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COMMON THINGS.

AIR.

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1. Of all common things, air is the most common. No space or place is accessible to us that is not filled with it. It is of all material wants that which is most incessantly indispensable to our existence. Food is an occasional want, an intermitting supply is all that is needed. Clothing may in certain cases be dispensed with, and habit may inure us to a deficiency of it. The want of warmth must be extreme to become fatal. But the privation of air, even for a brief interval, is attended with instant and certain death.

Unlike other natural wants, our consumption of air is not voluntary. The action of the lungs is like the oscillations of a pendulum. It is incessant, sleeping or waking, in sickness or in health; sitting, standing, or moving, it is maintained with a regularity and continuity quite independent of the will. Its suspension is the suspension of life.

Must we not then be prompted by a natural and irresistible curiosity to obtain some acquaintance with a physical agent so universal, so omnipresent, and so indispensable to our vitality?

2. Air is the transparent, colourless, invisible, light, and attenuated fluid with which we are always surrounded. It is drawn into our lungs by the action called suction, and after remaining a moment there, is forced out through the mouth and nose by the muscular compression of the chest. This alternate action, by which the air enters and leaves the lungs, is called respiration. During the moment it remains in the lungs, it undergoes a certain change, which we shall presently explain, in consequence of which, when expired, it is not the same as that which was inspired. The effect produced on the blood by this change is essential to the maintenance of life.

The air which, thus changed, is expired, is unfit for respiration. If, therefore, the same air be taken several times successively into the lungs, death must ensue.

3. The air around us, therefore, requires to be continually changed, that which we expire being carried away and replaced by fresh and pure air.

4. The apparent lightness of air, the freedom with which we move through it, and its invisibility, led the ancients to imagine that it was unsubstantial and immaterial, and hence the disembodied souls of the dead came to be called *spirits*, from the word *spiritus*, which signifies *air*.

5. It is a great mistake, however, to imagine that air is destitute of weight, that quality which is inseparable from whatever is material. Light it undoubtedly is, but only by comparison. Bulk for bulk, it is lighter than stone, earth, or water, or any other substance in the solid or liquid state. But light as it is, it has a certain definite weight, and a quantity of it can be assigned which will weigh many tons. The pressure produced by its weight is under certain assignable circumstances quite enormous, and when it is moved with a certain velocity its force is so irresistible that trees are torn by it from their roots, the most solid buildings overturned and reduced to ruins, and devastation spread over vast tracts of country.

Nothing can be easier than to show practically that air has weight, and what that weight is.

6. If a glass flask, having the capacity of a cubic foot, be provided with a proper neck, furnished with a stop-cock, we shall be able, by means of a well-constructed syringe, to extract from it the air which it contains, and by closing the stop-cock, and detaching the syringe, we shall have the flask void of air. Let it be weighed in that state in a good balance. Let the stop-cock be then opened so as to admit the air to fill the flask, and let it then be weighed again. It will be found to weigh 1·291 oz. or 564·8 grains more than it did when void of air.

It follows therefore that a cubic foot of air weighs 564·8 grains.

Since the weight of a cubic foot of water is 997·125 oz., it follows that, bulk for bulk, water is heavier than air in the proportion of 997·125 to 1·291, that is, of 772½ to 1.

Since thirty-six cubic feet of water weighs a ton, it follows that 772½ times thirty-six cubic feet of air also weighs a ton.

It appears, therefore, that 27810 cubic feet of air will weigh a ton.

7. When it is considered that the mass of air which taken collectively is called the ATMOSPHERE, extends above us to the height of more than fifty miles, it will easily be imagined that the weight with which it presses on the surface of every object exposed to it, must be very considerable. If, for example, we take a square inch of level surface, it is clear that that square inch must bear the weight of a column of air extending from that surface to the top of the atmosphere. It has been ascertained by experiments, susceptible of the greatest precision, (which we shall explain on another occasion) that this pressure or weight amounts to about 15lbs., and that it is subject, from time to time, to a variation not exceeding three quarters of a pound.

8. It is a well known property of fluids, that any pressure which

they exert, acts equally in all possible directions. Thus, if any body be let down into the sea, the weight of the water, which is above it, will press equally on its top, bottom, and sides. It is very easy to demonstrate this by a simple experiment.

Let several empty bottles be carefully corked, and being loaded with weights so as to sink in the water, the neck of one being presented upwards, that of another downwards, another horizontal, and the others oblique in various degrees, it will be found that when they have been sunk to a certain depth, the corks will be all forced into the bottles by the pressure of the surrounding water, with which the bottles will be immediately filled, and this will take place equally, and at the same time, with all the bottles, in whatever directions the corks may be presented to the water.

It is evident, therefore, that the pressure produced by the weight of the incumbent column of water at any given depth is equally propagated in all directions, and that a body, a fish for example, or the body of a diver, sustains that pressure, not downwards only, or on the upper surface of the body as might be at first imagined, but equally on the under surface, the sides, and, in a word, on every part of the body in contact with the water.

Now this equal transmission or propagation of pressure in all directions, is not an exclusive property of water, but is common to all substances whatever in the fluid state. Air possesses fluidity in even a greater degree, if possible, than water, being more freely mobile, and air accordingly transmits freely and without diminution in all directions whatever any pressure which it receives. The stratum of air in which we live is under the pressure, as has just been stated, of the incumbent column of air extending upwards to the limits of the atmosphere, this pressure amounting to 15 lbs. on each square inch. A body, therefore, exposed to the contact of this air is subject at all parts of its surface, upper, under, and lateral, to this pressure; and the total amount of the pressure by which it is affected will be expressed in pounds weight by the number obtained by multiplying the number of square inches in its entire surface by 15.

The body of a man of average size has a surface of about 2000 square inches. The total pressure which it sustains from the surrounding air is therefore 15 × 2000, or 30000 lbs., or nearly fourteen tons!

9. It may seem wonderful that a force so enormous, acting on all parts of the surface of the body, should not crush it and actually destroy its delicately constructed organs. This, however, is prevented by the perfect equilibrium of pressure outwards and inwards, produced by the property of fluids just explained, in

virtue of which they transmit freely, and undiminished, the pressure in all directions. The fluids which fill the entire vascular system are exposed, as well as the surface of the body, to the pressure of the atmosphere, which enters the lungs and all the cavities and open parts of the organs. These fluids transmit that pressure to all the inner parts of the body, so that the skin and integuments are pressed by them outwards by a force exactly equal to that with which the air presses the external surface of the skin inwards. These outward and inward pressures are necessarily always equal, because, in fact, they are one and the same pressure, *i.e.*, that of the air, the pressure on the external surface acting inwards, being the immediate action of the air, and the pressure of the internal fluids acting outwards being the same pressure of the air transmitted by those fluids to the inside of the skin and integuments.

10. That this outward pressure, transmitted by the fluids which fill the organs under the skin, is really at all times in operation, and that it is only counteracted by the immediate pressure of the external air upon the skin, is rendered conspicuously manifest in the well-known surgical operation of cupping. In that process the open mouth of the cupping-glass being pressed upon the skin so as to exclude all communication with the external air, the air within the cup is withdrawn, or partially withdrawn, by means of a syringe attached to the glass. The moment the skin within the glass is relieved from even a small part of the pressure of the external air by this means, the outward pressure of the fluids under the skin begins to take effect, being no longer resisted; it swells up the skin within the glass, and when the skin thus dilated is punctured with the lancet, the blood is propelled from it by the force of the pressure of the fluids under the skin acting outwards.

11. The free transmission of pressure in all directions is a property which air has in common with water and other liquids. It has, however, another quality eminently characteristic, which is not found in liquids, or any other form of matter. The property we refer to is unlimited compressibility.

Let a tube A B (fig. 1) be provided, open at one end A, and closed at the other B, and let a solid plug P be made to fit it air-tight. Let an opening, governed by a stop-cock, be provided at C. When the plug is inserted at A, the air inclosed by it in the tube will be in its natural state, provided the stop-cock be open, and the plug will be pressed upon it by the amount of the atmospheric pressure. If we suppose the plug to have the magnitude of a square inch, this pressure will be fifteen pounds.

The stop-cock C being closed, let the plug P be pressed down

with a force of fifteen pounds. If the tube were filled with water instead of air, the plug would in that case maintain its position, for the water would not yield in any degree to the pressure.

Fig. 1.

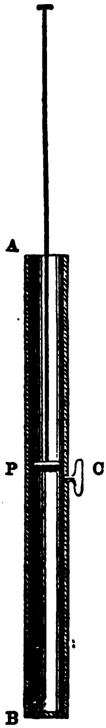
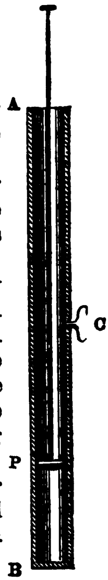


Fig. 2.



But the case is quite otherwise with air. The moment the pressure is applied, the plug will descend in the tube, squeezing or compressing the air into a less space, and it will continue to descend until the air is compressed half its original bulk. There the compression will cease, and the plug will remain at half its original distance from the bottom B of the tube, as in fig. 2.

Thus, if the original height of the plug P above the bottom of the tube were twelve inches, the plug being pressed downwards only by the atmospheric pressure, that is, by 15 lbs., its height, when pressed by 15 lbs. more, that is, by 30 lbs. in all, will be six inches. The air, which is compressed into twelve inches by 15 lbs., is therefore compressed into six inches by 30 lbs., the volume of the air being diminished in the exact proportion in which this compressing force is augmented.

This experiment may be carried farther with a like result. If the piston be forced down with a weight of 30 lbs., in addition to the atmospheric pressure, which is 15 lbs., the whole compressing force will be 45 lbs. In this case, the compressing force being augmented in the proportion of three to one, the space into which the air is compressed will be decreased in the same ratio, and the plug P will descend to four inches from the bottom B.

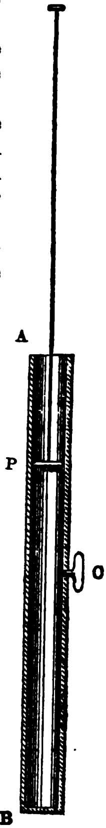
In general, therefore, the space into which air will be squeezed by any force will be less in exactly the proportion in which the compressing force is increased, it being well understood, nevertheless, that the original pressure of the external air, amounting to 15 lbs. per square inch, is to be included in the compressing force.

This property of unlimited and uniformly regular compressibility is one of the essential and characteristic properties of air, being one in which no other form of matter participates. Liquids are in general, for all practical purposes, absolutely incompressible. Some solids are compressible in a certain slight degree, but not at all in the general and regular way in which air is compressible.

ELASTICITY.

12. Air has another characteristic and highly important quality, called ELASTICITY, which, like its compressibility, is unlimited and uniform.

Fig. 3.



Let us suppose that the plug P in the tube A B, fig. 1, instead of being pressed down, is drawn upwards, the tube being long enough to allow it all the necessary play, as in fig. 3. If, in that case, water had filled the tube under the plug, a void space would remain between the surface of the water and the plug. In short, the elevation of the plug would be followed by no sensible change in the space occupied by the water. But when the tube contains air, the result is quite otherwise. In that case, when the plug is drawn upwards, the air which before filled the tube between the plug and the bottom now expands, and swells so as still to fill the increased space left open to it by the elevation of the plug, and this expansion will go on without any practical limit to whatever height the plug may be elevated.

This capability of swelling without limit into augmented dimensions when relieved from the conditions which confine it is called ELASTICITY. Like COMPRESSIBILITY, it is a characteristic property in which no other form of matter participates. Liquids are for all practical purposes inelastic. Some solid bodies possess a certain elasticity, but not at all identical in its character or laws with the elasticity of air above described.

13. It has been explained that air in its common state exercises a pressure of 15 lbs. on each square inch of surface with which it is in contact. It exercises this pressure equally whether it is in communication with the external atmosphere or not. In the case of the tube A B and plug P, the air in the tube, before the introduction of the plug, pressed on the surface of the tube with a force of 15 lbs. per square inch, because it sustained that pressure from the incumbent weight of the atmosphere, and transmitted that pressure freely and undiminished to the inner surface of the tube. But when the plug is introduced, all communication with the external air is cut off, and nevertheless the included air still presses on the surface of the tube with the same force. As this pressure cannot arise from the incumbent weight of the external air, all communication with which is intercepted by the piston, it is due altogether to the elasticity of the air confined within the tube.

The piston inserted in the tube in this case is therefore subject to the action of two equal forces. The WEIGHT of the external air

presses it *downwards* with a force of 15 lbs., and the ELASTICITY of the air confined within the tube presses it *upwards* with an equal force of 15 lbs. The piston is thus held in equilibrium, having no tendency either to rise or fall in the tube.

Indeed, the very fact that the piston inserted in the tube A B has no tendency to descend into it, and to compress the air under it, although it is urged downwards by the air above it with a force of 15 lbs., proves that the air below it must urge it upwards by a force exactly equal; since, if it were urged upwards by any less force, it would be pressed down by this excess of the force of the external air, and if it were urged upwards by any greater force than 15 lbs., it would ascend with the excess of this upward force.

Air, therefore, in its natural and usual state, has an elastic force of 15 lbs. per square inch, so that when it is shut up in any vessel or other envelope, and cut off from all communication with the external air, it will press on every square inch of the inner surface of such envelope with a force of 15 lbs.

14. This elastic force increases in the same proportion as the space in which the air is confined is diminished by compression, and it decreases in the same proportion as the space into which it is allowed to expand is increased. Thus, if we suppose that when the air fills twelve inches of the tube A B, fig. 1, it has an elastic force of 15 lbs., it will have an elastic force of 30 lbs. when it fills six inches of the tube; 45 lbs. when it fills four inches; 60 lbs. when it fills three inches, and so on. And in like manner when it is allowed to expand so as to fill twenty-four inches, its elastic force will be reduced to 7½ lbs.; when it expands to thirty-six inches, the elastic force will only be 5 lbs., and so on.

15. The stratum of air which rests on the surface of the earth, and in which the organised tribes that inhabit the earth live, derives its pressure, elasticity, and density from the weight of the whole mass of the atmosphere which rests upon it. It must, therefore, be evident, that if we ascend to greater elevations, leaving below us a certain stratum of the atmosphere, and having above us a proportionally less quantity of air, the weight of the incumbent air being less, the pressure, elasticity, and density of the stratum which surrounds us will be proportionally less. And we find this actually to be the case. At great heights on mountain chains, such as the Pyrenees or the Alps, the air is very sensibly rarefied. It is lighter, and exercises a much less pressure. In like manner, persons who ascend to great elevations in balloons find much inconvenience from the thinness of the air. The fluids confined within the body are much less resisted, certain organs become dilated, and the effect of a cupping-glass is occasionally produced, attended with bleeding at the nose, and singing in the ears.

16. The ancients imagined that air was a simple substance which entered more or less into the composition of bodies in general, and hence they called it one of the elements; the others being in their theory of physics, water, earth, and fire. Better informed now, we know that neither air, water, nor earth, are simple or elementary substances, and that fire is not a substance at all, but a physical effect due to the sudden and large production of heat which attends the chemical combination of certain substances. Thus the ancient elements are not elements at all.

But to return to air, the more immediate object of our attention at present.

17. Air—meaning by that term the air of the atmosphere, the air we breathe, the air through which we behold the firmament, the air whose currents carry our commerce over the ocean from land to land—is a compound or mixture made up of two extremely different kinds of air.

18. As there are many sorts of air having extremely different qualities and properties, although they are alike in appearance, being all invisible, transparent, colourless, light, compressible, and elastic, it has been found convenient to call them by the general name *gas* (derived from the Saxon word *gast*), and to limit the application of the term "air" to that particular compound or mixture of gases which constitutes the atmosphere.

19. The erroneous notion that air was a simple and elementary substance prevailed until the close of the last century, when Lavoisier, the celebrated French philosopher, who was one of the most illustrious of the founders of modern chemistry, showed that it was a mixture of two different gases in definite proportions, called oxygen, and azote or nitrogen.

A hundred cubic inches of air is a mixture consisting of 80 cubic inches of azote, and 20 of oxygen. The result of the most exact analyses differs from this proportion by a minute fraction, which, though not unimportant in certain respects, need not here embarrass the reader, who will do well to fix in his memory this proportion of 80 to 20.

There are many ways in which this constitution of atmospheric air may be made manifest, some of which, however, involve principles which would not be comprehended without a more extensive knowledge of chemistry than is expected from our readers in general. The following demonstration will, however, it is hoped, be understood without difficulty.

Let 100 cubic inches of common air, and 40 cubic inches of the gas called hydrogen, be introduced into a closed flask. If an electric spark be transmitted through this mixture, which may be easily done, an explosion will take place with a considerable development

of heat. When the flask has been cooled, and its contents examined, it will be found to contain eighty cubic inches of azote and a quantity of water, whose weight is exactly equal to the combined weights of twenty cubic inches of oxygen and forty cubic inches of hydrogen.

The inference from this experiment is, that, under the influence of the electric spark, one of the constituents of the air has entered into combination with the hydrogen, and that their compound is water; and since the air has lost twenty cubic inches, it follows that this portion of it is a gas which has the property of combining with twice its own measure of hydrogen, and thus forming water. The gas which possesses this property is called oxygen.

The experiment here described is attended with two results, both of which have high importance. It proves first that 100 cubic inches of common air consists of eighty cubic inches of azote, and twenty of oxygen; and, secondly, that twenty cubic inches of oxygen mixed with forty of hydrogen will be converted into water by passing through them the electric spark.

It now remains to explain the chief properties of the two gases, by the mixture of which, in the proportion of eighty to twenty, or four to one, common air is formed.

20. Azote, or nitrogen, which thus forms four-fifths of the air we respire, is characterised by negative rather than positive qualities. It has neither colour, taste, nor odour. A candle or lamp is immediately extinguished when introduced into it. No animal which requires respiration can live in it.

Although this inability to support life by respiration is not peculiar to this particular gas, it has nevertheless given to it the name azote, from two Greek words signifying the negation of life.

This gas is not inflammable.

The destructive influence of this gas on animal life does not arise from any poisonous or injurious quality in the gas itself, but altogether from the absence of oxygen.

This gas, when compressed by the same force, is very little different in weight from common air. A hundred cubic inches of it weigh $30\frac{1}{8}$ grains, while 100 cubic inches of common air weigh 31 grains.

21. The other constituent of atmospheric air, called oxygen, is characterised by many very remarkable properties.

Like azote, this gas has neither colour, taste, nor odour. Bulk for bulk, and under equal pressure, it is a little heavier than common air, 100 cubic inches weighing $34\frac{1}{5}$ grains.

The properties which are most conspicuously characteristic of this gas are those which relate to combustion and respiration.

22. Combustion, or burning, is a phenomenon which consists of

the large and sudden evolution of heat and light arising from the combination of a class of bodies, called combustibles, with oxygen.

If a piece of charcoal be heated to redness, it will immediately begin to combine chemically with the oxygen of the atmosphere. A great heat and a vivid light are produced in this combination, and the product of it is a compound gas, composed of oxygen and carbon, and called carbonic acid.

In like manner, if sulphur or phosphorus be similarly heated, similar effects will ensue.

But since it is evident that these phenomena thus produced in common air arise exclusively from the presence of oxygen, which nevertheless forms only a fifth part of that air, it may naturally be inferred that if the same combustibles were placed in an atmosphere containing a greater portion of oxygen, and still more if they were placed in an atmosphere of pure oxygen, the phenomena would be far more vivid.

And this is accordingly found to be the case.

All substances, which are capable of burning in common air, burn with far greater intensity and splendour in an atmosphere of pure oxygen. A piece of wood on which the least spark of light is visible, which would be spontaneously extinguished in common air, will burst into flame the moment it is plunged in a jar of pure oxygen. A piece of charcoal, heated to redness at its point, will in like circumstances enter into vivid combustion, emitting the most brilliant scintillations, until it altogether disappears. Phosphorus similarly treated burns with a light too splendid to be looked at without pain. If the extremity of a coil of steel wire be heated to redness, and plunged in such a jar, the wire will be rapidly burnt, emitting in like manner streams of brilliant sparks.

These substances severally disappear in the process of combustion, and before science had attained to its present state of advancement it was supposed that they were destroyed. It is now known that the destruction of matter, in any form, and by any natural process, is as impossible as its creation. It is a physical maxim of high generality and undoubted truth that nothing but the immediate operation of the Divine will can either augment or diminish the quantity of matter composing the world. Whenever ponderable matter, therefore, seems to disappear, we are called upon to trace it, to discover its hiding-place, and to explain the nature and the cause of the change which produces its disappearance. In the present case nothing is easier.

23. Let us suppose, for example, that a piece of lighted charcoal of sufficient magnitude is plunged in a closed glass jar filled with

pure oxygen gas. The vivid combustion of the charcoal will take place, and will be continued for a certain time, when it will cease, becoming continually less vivid until it is extinguished. If the gas now contained in the jar be examined by the usual chemical test, it will be found that it is no longer oxygen. A taper plunged in it will be instantly extinguished. An animal placed in it will die. Its weight will be greater than that which it had previously to the experiment, and if the unburnt residue of the charcoal be weighed it will be found to have lost precisely the weight which the gas has gained.

In a word, the oxygen gas has been converted into another and heavier gas, called carbonic acid, and this has been accomplished by a portion of the charcoal entering into chemical combination with it, that combination being attended with the evolution of heat and light, which characterises the phenomenon of combustion or burning.

24. Now it is most desirable to become familiar with the character and properties of this gas, for it plays a most important part in numberless processes and phenomena natural and artificial, which we encounter daily and hourly in the common experience of life.

Like all other gases, carbonic acid in its ordinary state is invisible, colourless, compressible, and elastic. It has a pungent smell and acidulous taste. If reduced to the temperature of melting ice and compressed with a force of 36 atmospheres, that is of 36×15, or 540 lbs. per square inch, it is reduced to a liquid, and when reduced to 180° below zero of Fahrenheit's thermometer, it is frozen and becomes solid.

25. This gas is altogether unfit for respiration. When breathed pure it produces a violent spasm of the organ of the throat called the glottis, which prevents the gas from entering the lungs. If, however, it be mixed with so much common air as to prevent it from producing this spasm, it may enter the lungs, and in that case it acts on the system as a narcotic poison.

26. All substances used for warming rooms, such as coal, coke and wood, and all such as are used for lighting them, such as oil, tallow, wax, consist chiefly of carbon combined in small proportions with other constituents. The chief product of the combustion of all such substances is therefore carbonic acid. When coal, or other fuel, is burnt in a grate or stove, the carbonic acid is carried away by the chimney or flue, and therefore does not pollute the air of the room. But this is not the case with the carbonic acid produced by the candles and lamps used to illuminate the room. All the carbonic acid produced by them mixes with the atmosphere of the room and poisons it to

a proportionate degree. As this gas is evolved in the flame of the lamps and candles in a heated and highly expanded state, it will ascend to the ceiling of the room, and will float in a stratum there for a certain time. If means are not provided for its escape it will soon descend into, mix with, and poison the air of the room, and render it injurious to the health of those who breathe it.

27. In theatres and other large buildings, which are sometimes illuminated by a central chandelier suspended from the ceiling, an opening is provided over the chandelier, which permits the escape of the carbonic acid, exactly as the chimney of a fireplace or the flue of a stove receives that which is produced by the combustion of the fuel. In all cases whatever, the healthiness of apartments would be greatly increased if similar openings were provided for the escape of the carbonic acid produced by lamps, candles, and other causes.

28. The effervescence of soda water, champagne, ale, beer, and other similar drinks is produced by carbonic acid, which is fixed in them, and suddenly liberated when relieved from the confining pressure by the withdrawal of the cork. The agreeable pungency of these liquors is in a great degree due to the presence of this carbonic acid, which being allowed to escape by exposure in the air, or by leaving the bottle uncorked, the drink becomes stale and flat.

Water commonly contains more or less carbonic acid fixed in it. This being expelled by the process of boiling, cold boiled water acquires a peculiarly insipid taste, owing to the absence of the acid gas.

It appears that the reception of carbonic acid gas into the stomach is not attended with the same deleterious effects as are produced by its introduction into the lungs. There are few forms of food or drink which do not include more or less of it.

In general, fermentation is attended with the evolution of carbonic acid. The gas ejected from dyspeptic stomachs affected by flatulency is carbonic acid.

29. This gas is abundantly generated in all the spontaneous changes which attend the corruption of dead animal and vegetable matter. In autumn, after the fall of the leaf in woods, forests, and gardens, and in all places where dead leaves are allowed to accumulate, the air is more or less impregnated with carbonic acid, which, by reason of its weight, remains long collected in the lower strata of the air, rendering it unhealthy.

30. This gas is often collected and retained in the bottom of old wells, where it is known under the name of *choke-damp*. An animal which descends in such a well dies.

It sometimes issues from the earth, being evolved in some subterraneous process. Examples of this are presented in the case of the celebrated Grotto del Cane in Italy, and at Pyrmont, in Westphalia. The former place takes its name from the cruel and now useless experiment of showing that a dog let down into it dies.

31. Carbonic acid is so much heavier than air, that it may be decanted like a liquid from one vessel to another. It is, however, a mistake to suppose that in consequence of its relative weight, it will permanently sink to the lowest strata of the atmosphere on which it happens to be placed, on the same principle that water would sink to the bottom of oil. Gases in general are subject to a physical law, in virtue of which they mingle one with another when they are in contact, and become at length uniformly diffused through each other, notwithstanding these differences of weight.

A small proportion of this gas is always diffused through the atmosphere, being the produce of innumerable natural processes which take place on the surface of the earth. This is not to be regarded, however, as a constituent of common air, any more than the mud of the Mississippi or the Tiber, or the salt of the ocean, is to be considered as a constituent part of pure water.

32. Carbonic acid is evolved in large quantities by respiration. The oxygen, which forms one-fifth part of the common air which is inspired in respiration, is absorbed by the blood before it enters the arterial system, and the same blood on issuing from the venous system dismisses a corresponding quantity of carbonic acid, which is expired at the mouth and nostrils. Thus, while the air inspired is a mixture of azote and oxygen, the air expired is a mixture of azote and carbonic acid.

The effect, therefore, of respiration on the surrounding air is precisely the same as that of a lamp or candle. In both cases the oxygen constituent disappears, and is replaced by carbonic acid.

It is evident, therefore, that it is the oxygen constituent of common air which is the means of supporting animal life by a specific effect which it produces upon the blood which absorbs it, and which carries it through the arterial and venous systems, where it is converted into carbonic acid, and discharges a variety of functions necessary to the maintenance of life.

33. It is for this reason that oxygen is often called VITAL AIR.

34. In apartments or buildings where persons are crowded together in large numbers, more especially when they are illuminated by artificial light, there is therefore an enormous and rapid production of this noxious gas, as well by respiration as by the lamps, candles, or gas-burners used for illumination.

Although in large public buildings which are habitually thus filled, proper means of ventilation are often provided, this is not the case in general in private residences, where such assemblies are only occasional. Hence it happens that large parties, balls, and other social entertainments given in private houses are extremely injurious to the health. Multitudes are crowded together in brilliantly-lighted rooms. The respiration, the exhalation from the skin produced by an elevated temperature and by the exercise of dancing, and the combustion of vast numbers of candles, lamps, and gas-lights, evolve carbonic acid in large quantities, which, having no means of escape, accumulates until the company becomes painfully sensible of its ill-effects on respiration. Relief is then sought by opening one or more windows or doors, by which currents of fresh air are let in, and the foul air drawn out. If the air thus admitted were of a proper temperature, this palliative of the evil might be admitted to be partially efficient; but the air thus introduced is usually of a temperature from twenty to forty degrees lower than that of the room. The persons exposed to these sudden cold currents, more especially females, having their highly heated skins and open pores extensively uncovered, receive a chill, by which the integument contracting drives back into the blood the fluids which ought to have been permitted to escape by cuticular transpiration. Hence arise numberless diseases, rheumatisms, colds, fevers, and in more cases than is ever known or acknowledged, premature and ultimate death.

35. It will be apparent from these considerations how much it behoves architects, builders, and proprietors to provide proper expedients in the erection of private residences for the efficient ventilation of rooms.

36. We have stated that air is colourless and transparent, and this is practically true not only of common air, but of gases generally, when they are exhibited in such moderate quantities as are usually submitted to observation or experiment. Strictly speaking, however, air is not absolutely transparent or absolutely free from colour.

When a fluid is very faintly coloured, its peculiar hue is only perceptible when a considerable depth or thickness of it is submitted to view. If a tapering glass, such as those used for champagne, be filled with pale sherry or other liquor of a like colour, the peculiar colour of the liquid will be distinctly enough perceived at the top of the glass, when the eye views a certain thickness of it; but the colour becomes fainter and fainter towards the point of the cone, where it is scarcely perceptible. If a glass tube of small bore be dipped in the liquid, and, the

finger being applied at the upper end to stop it, it be raised, the liquid which will be suspended in the tube will appear as transparent and colourless as water. It cannot be doubted, nevertheless, that the liquid in the tube has the same colour as the liquid in the glass. The colour is not perceived only because the quantity in the tube is too small to reflect sufficient colour to produce a sensible effect on the eye.

The atmosphere is in the same circumstances. The colour reflected even from a considerable volume of it is too faint to be perceptible. Thus the air which fills a room, or which intervenes between the eye and the buildings, trees, and other objects around us, appears quite transparent and colourless, and we see all such objects distinctly through it in their proper colours. But when, in the daytime, we look up through fifty or sixty miles height of air, illuminated by solar light, we find that a strong and decided tint of blue is perceived. This azure, which in the absence of clouds forms the celestial vault, belongs not to anything which occupies the regions of the universe in which the heavenly bodies are placed, but to the vast mass of air through which these bodies are seen.

To perceive this peculiar colour of air, however, it is not necessary that so vast a mass should be presented to the eye. Distant mountains appear bluish, not because that is their colour, but because it is the hue of the aërial medium through which we look at them. As we approach them, the quantity of the intervening air being diminished, this bluish tint is no longer perceived, and they appear with their proper colours.

NEW YORK HARBOUR.

LOCOMOTION BY RIVER AND RAILWAY

IN THE UNITED STATES.

CHAPTER I.

1. Natural apparatus of internal communication in United States.—2. Canal navigation.—3. Erie Canal.—4. Extent of canals.—5. Total cost, and cost per mile.—6. Extent of canals as compared with population.—7. River and coast navigation in United States.—8. Steam navigation on Hudson.—9. Tables of Hudson steamers.—10. Beautifully finished machinery and structure.—11. Their great speed.—12. Application of expansive principle.—13. Explosions on eastern rivers rare.—14. Description of paddle-boards and mode of working steam in steamers of eastern rivers.—15. Power of engines.—16. Fares reduced with increased size of vessels—Form and structure of Hudson steamers.—17. Description of the navigation of that river.—18. Steam navigation of other American rivers.—19. Mississippi steam-boats.—20. Cause of explosions.—21. Magnitude and splendour of boats.—22. Extent of the navigation of the Mississippi valley.

1. No quarter of the globe presents a natural apparatus of internal communication so stupendous as that which the European settlers found at their disposal on the North American continent.

This immense tract, included between the Atlantic and the Rocky Mountains on the east and west, the great chain of lakes extending from Lake Superior to Lake Ontario on the north, and the Gulf of Mexico on the south, is divided into two districts by the ridge of the Alleghanies, which traverses it in a direction north and south. The western division consists of the vast valley drained by the Mississippi and its tributaries, a territory greater in superficial extent than Western Europe. The eastern district consists of that portion between the Alleghany ridge and the Atlantic, falling towards the ocean and drained by innumerable rivers, navigable for vessels of greater or less burthen, and running generally eastward.

Provided with such means of water communication, it might have been expected that a population thinly scattered over an area so extensive, and engrossed by the exigencies of incipient agriculture, would have continued for ages contented with means of transport afforded them on so vast a scale, without having recourse to the resources of art.

It is, however, the character of man, and more especially of Anglo-Saxon man, never to rest satisfied until he renders the gifts of nature, however munificent, ten times more fruitful by his industry and skill; and it will be presently seen to what a prodigious extent the enterprise of the population of the United States has improved these means of inland transport.

I. Canal Navigation.

2. The spectacle of a machinery of commerce so imposing in magnitude and power, and so remarkably co-extensive with the vastness, the fertility, and the mineral wealth of the territory of which this emigrant people found themselves possessors, only provoked their ambition to rival the enterprise of the parent country, and to import and naturalise its improvements and its arts. Their independence was scarcely established before the same resources of art and science which ages had not been more than sufficient to develop in Britain were invoked; and a system of artificial communication was undertaken, and finally executed, on the new continent, for which, all things considered, there is no parallel in the history of civilisation.

Immediately after the acknowledgment of the independence of the American colonies by England in 1783, several companies were formed in the two principal states of the Union, those of

New York and Pennsylvania, for the purpose of constructing a system of canals. These enterprises were accordingly commenced, but on a scale too limited for the attainment of the ultimate objects; and as the United States advanced in commercial prosperity, more extensive plans were adopted. In 1807, the senate charged the Secretary of State, Mr. Galatin, to prepare a project for a general system of intercommunication by canals, based upon the geographical character of the territory of the Union.

A system of artificial water-communication was accordingly projected, which, with some modifications, was at a later period adopted and carried into execution.

These projects, however, suffered an interruption from the renewal of the war in 1812; and it was not until five years later that the vast works were commenced, the result of which has been a system of inland navigation which is without a rival in any country in the world.

3. On the anniversary of the declaration of independence celebrated the 4th July, 1817, the commencement of the great line of canal connecting the Hudson with Lake Erie was inaugurated. The river Hudson presented a navigable communication for vessels of a large class from New York to Albany. The object of this line of canal was to open a water-communication between Albany and the northern lakes, so as to connect, by continuous water-communication, the North-Western States with the Atlantic.

In less than eight years this work was accomplished by the state of New York, with its exclusive resources.

That state alone executed and brought into operation the largest canal in the world. As first constructed, the Erie canal, with its branches, cost 2,600000*l*. sterling; but its magnitude and proportions being still found inadequate to the exigencies of a continually increasing traffic, its enlargement was decided upon in 1835, and it was finally completed, at a cost of upwards of 5,000000*l*. sterling. The total length of this canal is 363 miles, and its cost of construction per mile was therefore about 13700*l*.

Meanwhile, the other states of the Union did not remain inactive. Pennsylvania especially rivalled New York in these enterprises, and became intersected with canals in all directions. In short, these works were undertaken to a greater or less extent in most of the Atlantic and some of the Western States; and the American Union now possesses a system of internal artificial water-communication amounting to nearly 4500 miles, executed with a degree of skill and perfection rarely surpassed by any similar works constructed in the states of Europe.

4. According to M. Michel Chevalier, whose work on this

subject supplies most voluminous and valuable details,* the extent of canals which were in operation in the United States on January, 1, 1843, was 4333 miles. There was a further extent projected, but not executed, amounting to 2359 miles.

5. The total cost of executing the canals which were completed was, according to M. Chevalier, 27,870964*l.*, being at the average rate of 6432*l.* per mile.

Since the date of these returns considerable extension has been given to the system of canal navigation by the opening of new lines and the increased length of former ones, and it is probable that the actual extent of artificial water-communication now in use in the United States considerably exceeds 5000 miles. The average cost of executing this prodigious system of water-roads was at the rate of 6432*l.* per mile, so that 5000 miles would have absorbed a capital of above 32,000000*l.*

6. This extent of canal transport, compared with the population, exhibits in a striking point of view the activity and enterprise which characterise the American people. In the United States there is a mile of canal navigation for every 5000 inhabitants, while in England the proportion is a mile to every 9000 inhabitants, and in France a mile to every 13000. The ratio, therefore, of this instrument of intercommunication in the United States is greater than in the United Kingdom, in proportion to the population, as 9 to 5, and greater than in France in the ratio of 13 to 5.

II. River Navigation.

7. The river navigation of the United States is on a scale commensurate with the extent of their territory. The division of the country east of the Alleghanies, forming the Atlantic States, is drained by a vast number of rivers, of the first and second class, all navigable for vessels of considerable burthen, the principal of which are the Hudson, the Delaware, the Susquehanna, the Connecticut, the Potomac, the James, the Roanoke, the Savannah, and, to the southwards, the Atamala and the Alabama.

The western division is drained by the Mississippi and its hundred tributaries, navigable for vessels of great tonnage for several thousands of miles.

Besides the internal communication supplied by rivers, properly so called, a vast apparatus of water transport is derived from the geographical character of the extensive coast, stretching for about four thousand miles, from the Gulf of St. Lawrence to the

* "Histoire et Description des Voies de Communication aux États Unis, et des Travaux d'Art qui en dépendent," par Michel Chevalier. Paris, 40—1843.

delta of the Mississippi, indented and serrated in every part with natural harbours and sheltered bays, fringed with islands, forming sounds, throwing out capes and promontories, which inclose arms of the sea, in which the waters are free from the roll of the ocean, and which, for all the purposes of internal navigation, have the character of rivers and lakes. The lines of communication, formed by the vast and numerous rivers, are completed in the interior by chains of lakes, presenting the most extensive bodies of fresh water in the known world.

8. Whatever may be the dispute maintained among the historians of art as to the conflicting claims for the invention of steam navigation, it is an incontestable fact that the first steam-boat practically exhibited for any useful purpose, was placed on the Hudson to ply between New York and Albany in the beginning of the year 1808. From that time to the present, this river has been the theatre of the most remarkable series of experiments on locomotion on water ever recorded in the history of man.

The Hudson rises near Lake Champlain, the easternmost of the great chain of lakes or inland seas which extend from east to west across the northern boundary of the United States. The river follows nearly a straight course southwards for two hundred and fifty miles, and empties itself into the sea at New York. The influence of the tide is felt as far as Albany, above which the stream begins to contract. Although this river, in magnitude and extent, is by no means equal to several others which intersect the States, it is nevertheless rendered an object of great interest by reason of the importance and extent of its trade. The produce of the state of New York, and that of the banks of the lakes Ontario and Erie, are transported by it to the city; and one of the most extensive and populous districts of the United States is supplied with the necessary imports by its waters. A large fleet of vessels is constantly engaged in its navigation; nor is the tardy but picturesque sailing vessel as yet excluded by the more rapid steamer. The current of the Hudson is said to average nearly three miles an hour; but as the ebb and flow of the tide are felt as far as Albany, the passage of the steamers between that place and New York may be regarded as equally affected by currents in both directions. The passage, therefore, whether in ascending or descending the river, is made in the same time.

This river is navigable by steamers of a large class as far as Albany, nearly one hundred and fifty miles above New York.

Attempts have been made, but hitherto without much success, to push the navigation a few miles higher, as far as the important town of Troy. The impediments arising however from the shallowness of the river appear to be so serious, that Albany has

continued, and probably will continue, to be the limit of steam navigation in this direction.

The steam navigation of the Hudson is entitled to attention, not only because of the immense traffic of which it is the vehicle, but because it forms a sort of model for most of the rivers of the Atlantic States. This navigation is conducted, as will be seen, in a manner and on a principle altogether different from that which prevails on the Mississippi and its tributaries.

In the steam-vessels used on these rivers, no other strength or stability is required than is sufficient to enable them to float and bear a progressive motion through the water. Not having to encounter the agitated surface of an open sea, they are supplied with neither rigging nor sails, and are built exclusively with a view to speed. Compared with sea-going steamers, they are slender and weak in their structure, with great length in proportion to their beam, and a very small draft of water.

The position and form of the machinery are affected by these circumstances. Without the necessity of being protected from a rough sea, the engines are placed on the deck in a comparatively elevated situation. The cylinders of large diameter and short stroke, almost invariably used in sea-going ships, are rejected in these river boats, and the proportions are reversed,—a comparatively small diameter and a stroke of great length being adopted. It is but rarely that two engines are used. A single engine, placed in the centre of the deck, drives a crank placed on the axle of the enormous paddle-wheels. The great magnitude of these latter, and the velocity imparted to them, enable them to perform the office of fly-wheels, and to carry the engine through its dead points with but little perceptible inequality of motion. The length of stroke adopted in these engines supplies the means of using the expansive principle with great effect.

The steamers which navigate the Hudson are vessels of great magnitude, splendidly fitted up for the accommodation of passengers; and this magnitude and splendour of accommodation have been continually augmented from year to year to the present time.

9. In the following table (p. 23) we have given the dimensions of nine steamers which were worked on the Hudson previously to 1838.

Since the date of these returns, considerable changes have been made in the proportion and dimensions of the vessels navigating this river; all these changes having a tendency to augment their magnitude and power, to diminish their draft of water, and to increase the play of the expansive principle. Increased length and beam have been resorted to with great success. Vessels of the largest class now draw only as much water as the smallest a few years ago: 4ft. 6in. is now regarded as the maximum.

HUDSON STEAMERS.

Names.	Length of Deck.	Breadth of Beam.	Draft.	Diameter of Wheel.	Length of Paddles.	Depth of Paddles.	Number of Engines.	Diameter of Cylinder.	Length of Stroke.	Number of Revolutions.	Part of Stroke at which Steam is cut off.
	ft.	ft.	ft.	ft.	ft.	in.		in.	ft.		
Dewit Clinton .	230	28	5·5	21	13·7	36	1	65	10	29	$\frac{3}{4}$
Champlain .	180	27	5·5	22	15	34	2	44	10	27·5	$\frac{1}{2}$
Erie . . .	180	27	5·5	22	15	34	2	44	10	27·5	$\frac{1}{2}$
North America .	200	30	5	21	13	30	2	44·5	8	24	$\frac{1}{2}$
Independence .	148	26	—	—	—	—	1	44	10	—	
Albany . .	212	26	—	24·5	14	30	1	65	—	19	
Swallow . .	233	22·5	3·75	24	11	30	1	46	—	27	
Rochester .	200	25	3·75	23·5	10	24	1	43	10	28	
Utica . . .	200	21	3·5	22	9·5	24	1	39	10	—	
Providence .	180	27	9	—	—	—	1	65	10	—	
Lexington . .	207	21	—	23	9	30	1	48	11	24	
Narragansett .	210	26	5	25	11	30	1	60	12	—	$\frac{1}{2}$
Massachusetts .	200	29·5	8·5	22	10	28	2	44	8	26	
Rhode Island .	210	26	6·5	24	11	30	1	60	11	21	

In the following table we have exhibited the dimensions and other particulars of nine of the most efficient of the more recently built steamers plying on the Hudson and its collateral streams; and by a comparison of this with the former table, it will be seen to what an extent the dimensions and efficiency of these vessels have been increased.

Name of Vessel.	Dimensions of Vessel.				Engine.			Paddle-Wheel.		
	Length.	Beam.	Depth of Hold.	Tonnage	Diameter of Cylinder.	Length of Stroke.	Number of Strokes.	Diameter.	Length of Bucket.	Depth of Bucket.
	ft.	ft. in.	ft. in.		in.	ft.		ft. in.	ft in.	in.
Isaac Newton .	333	40 4	10 0	—	81	12	18½	39 0	12 4	32
Bay State . .	300	39 0	13 2	—	76	12	21½	38 0	10 3	32
Empire State .	304	39 0	13 6	—	76	12	21½	38 0	10 3	32
Oregon . .	305	35 0	—	—	72	11	18	34 0	11 0	28
Hendrik Hudson	320	35 0	9 6	1050	72	11	22	33 0	11 0	33
C. Vanderbilt .	300	35 0	11 0	1075	72	12	21	35 0	9 0	33
Connecticut . .	300	37 0	11 0	—	72	13	21	35 0	11 6	36
Commodore .	280	33 0	10 6	—	65	11	22	31 6	9 0	33
New World . .	376	35 0	10 0	—	76	15	18	44 6	12 0	36
Alida . .	286	28 0	9 6	—	56	12	24½	32 0	10 0	32

10. It is not only in dimensions that these vessels have undergone improvements. The exhibition of the beautifully finished machinery of the English Atlantic steamers did not fail to excite the emulation of the American engineers and steam-boat proprietors, who ceased to be content with the comparatively rude though efficient structure of the mechanism of their steam-boats. All the vessels more recently constructed are accordingly finished and even decorated in the most luxurious manner. In respect of the accommodations which they afford to passengers, no water-communication in any country in the world can compare with them. Nothing can exceed the splendour and luxury of the furniture. Silk, velvet, and the most expensive carpeting, mirrors of immense magnitude, gilding and carving, are used profusely in their decorations. Even the engine-room in some of them is lined with mirrors. In the Alida, for example, the end of the room containing the engine is composed of one large mirror, in which the movements of the highly-finished machinery are reflected.

11. The new and largest class of steamers are capable of running from twenty to twenty-two miles an hour, and make, on an average, eighteen miles an hour. These extraordinary speeds are obtained usually by rendering the boilers capable of carrying steam from forty to fifty pounds pressure above the atmosphere, and by urging the fires with fanners, worked by an independent engine, by which the furnaces can be forced to any desired extent.

It is right to observe here that this extreme increase of speed is obtained at a disproportionately increased consumption of fuel. When the speed is increased, the space through which the vessel must be propelled per minute is increased in the same proportion: and, at the same time, the resistance which the moving power has to overcome is augmented in the proportion of the square of the speed. Hence, the effect to be produced by the moving power per minute, is increased by two causes: first, the actual resistance which it has to overcome is augmented in the ratio of the square of the speed; and, secondly, the space through which the moving power has to act against this resistance in each minute is increased in the ratio of the speed. Thus, the total expenditure of moving power per minute will be augmented in the proportion of the cube of the speed.

Let us suppose the speed to be increased, for example, from eighteen to twenty-one miles an hour: the power to be expended per minute to produce this effect must be increased in the ratio of the cube of 18 to the cube of 21; or, what is the same, in the ratio of the cube of 6 to the cube of 7, that is, in the ratio of 216 to 343, or as 3 to 5 very nearly.

Hence, if the furnaces could be worked with equal economy, an

increased consumption of fuel per hour would be necessary in the proportion of 3 to 5; but the waste incurred by urging the blowers so as to produce a sufficiently vivid combustion is so great, that it is practically found that the consumption of fuel is increased in a much higher ratio than that which results from the increased resistance, and indeed in some cases that the increase of three or four miles an hour on eighteen miles will cause nearly triple the consumption of fuel.

12. Much of the efficiency of these engines arises from the application of the expansive principle; but to this there has been hitherto a limit, owing to the inequality of the action of the piston when urged by expanding steam on the crank. When the steam is cut off at less than half-stroke, the force of the piston is diminished before the termination of the stroke to less than one half its original amount. This inequality is aggravated by the relative position of the crank and connecting rod, the leverage diminishing in nearly the same proportion as the power of the piston diminishes. On this account it has not been found generally practicable to cut off the steam at less than half-stroke.

13. It must be observed, in relation to the navigation of these eastern rivers, that the occurrence of explosions is almost unheard-of. During the last ten years, not a single catastrophe of that kind has occurred on them, although cylindrical boilers ten feet in diameter, and composed of plating $\frac{5}{16}$ths of an inch thick, are commonly used with steam of fifty pounds pressure above the atmosphere.

14. It will be seen by the table given above, that the paddle-wheels used on these rivers have extraordinary magnitude. There is nothing particular in their construction. The split paddle-board, which was adopted about ten years since, has been discontinued, and has given way to the simple and continuous paddle-board. These boards, however, are generally placed alternately at greater and less distances from the centre, somewhat like a break-joint. Wooden spokes, with cast-iron centre pieces, are generally adopted.

The steam is universally worked with expansion, the valves for its admission and emission being moved independently of each other. A separate engine is generally provided for driving the blowers, and a cylindrical fan-blower is employed for each boiler. Some of these blowers are ten feet in diameter, being driven by a crank placed on their axle, which receives its motion from the small independent engine.

15. The great power developed by these river engines is due, not so much to the magnitude of their cylinders, as the pressure of steam used in them. Some of the most recently constructed

boats have cylinders seventy-six inches in diameter, and fifteen feet stroke. The steam has forty pounds pressure in the boiler, and is cut off at half-stroke. The wheels, which are forty-five feet in diameter, make sixteen revolutions per minute. The speed of the circumference of the wheel will therefore be twenty-five miles an hour; so that, if the speed of the boat be twenty miles an hour, we have the difference, five miles, giving the relative movement of the edge of the paddle-boards through the water.

To ascertain the power developed by these engines, let us suppose the mean effective pressure on the piston, taking into account the degree of vacuum produced by the condenser, and supposing the steam to be cut off at half-stroke, to be 40 lbs. per square inch, the area of the piston 4536 square inches, and the stroke 15 feet; the piston moves through 30 feet during each revolution of the wheels; and since 16 revolutions take place per minute, we shall find the effective force developed by the piston by multiplying its area, 4536, by twice the length of the stroke, which is 30, and by 16, which is the number of revolutions per minute. This product multiplied by 40, the number of pounds effective pressure per square inch, gives 87,091200 lbs. raised one foot high per minute as the power developed by the engine. This is equivalent, according to the ordinary mode of expressing steam power, to 2,640 horse power.

Whatever allowance, therefore, may be made for friction, &c., it is clear that the effective power thus obtained must be greater than anything hitherto executed on water.

The increase of the dimensions of these vessels and their machinery has been attended with a greatly augmented economy of fuel.

On comparing the Hendrik Hudson, for example, with the Troy, a vessel formerly well known, plying between New York and Albany, it has been found that when the speed of the former is reduced to an equality with that of the latter, the trip between New York and Albany being performed in the same time, the former consumed thirteen tons of coal while the latter consumed twenty; yet the displacement of the Hendrik Hudson, owing to its increased dimensions, is nearly twice that of the Troy.

The ease with which these vessels of extraordinary length and beam and small draft move through the water is very remarkable. The results of their performance show that the resistance per square foot of immersed midship section is not perceptibly increased by the increased length of the vessel, and the consequently augmented surface and friction. This anomaly has not been explained, but it is certain that the increased length does not h the effect of the moving power in any perceptible degree.

16. Practical evidence of the economy arising from this increase of power and dimensions is supplied by the fact that the proprietors of the Hudson steam-boats reduced their tariff for passengers, as well as for freight, as they increased the size of their vessels.

Previously to 1844 the lowest fare from New York to Albany, a distance of 145 miles, was 4*s*. 4*d*.; at present the fare is 2*s*. 2*d*.; and for an additional sum of the same amount the passenger can command the luxury of a separate cabin. When the splendour and magnitude of the accommodation is considered, the magnificence of the furniture and accessories, and the luxuriousness of the table, it will be admitted that no similar example of cheap locomotion can be found in any part of the globe. Passengers may there be transported in a floating palace, surrounded with all the conveniences and luxuries of the most splendid hotel, at the average rate of twenty miles an hour, for less than *one-sixth of a penny per mile!*

It is not an uncommon occurrence during the warm season to meet persons on board these boats who have lodged themselves there permanently, in preference to hotels on the banks of the river. Their daily expenses in the boat are as follow:—

	s.	*d.*
Fare	2	2
Separate bed-room	2	2
Breakfast, dinner, and supper	6	6
Total daily expense for board, lodging, attendance, and travelling 150 miles at 20 miles an hour	10	10

Such accommodation is, on the whole, more economical than an hotel. The bed-room is as luxuriously furnished as the handsomest chamber in an hotel or private house, and is much more spacious than the room similarly designated in the largest packet ships.

To obtain an adequate notion of the form and structure of one of the first-class steam-boats on the Hudson, let it be supposed that a boat is constructed similar in form to a Thames wherry, but above 300 feet long and 25 or 30 feet wide. Upon this, let a platform of carpentry be laid, projecting several feet upon either side of the boat, and at stem and stern. The appearance to the eye will then be that of an immense raft, from 250 to 350 feet long, and some 30 or 40 feet wide. Upon this flooring let us imagine an oblong rectangular wooden erection, two stories high to be raised. In the lower part of the boat, and under the flooring just mentioned, a long narrow room is constructed, having a series of berths at either side, three or four tiers high. In the centre

of this flooring is usually, but not always, enclosed an oblong, rectangular space, within which the steam machinery is placed, and this enclosed space is continued upwards through the structure raised on the platform, and is intersected at a certain height above the platform by the shaft or axle of the paddle-wheels.

These wheels are propelled, generally, by a single engine, but occasionally, as in European states, by two. The paddle-wheels are usually of great diameter, varying from 30 to 40 feet, according to the magnitude of the boat. In the wooden building raised upon the platform, already mentioned, is contained a magnificent saloon devoted to ladies, and to those gentlemen who accompany them. Over this, in the upper story, is constructed a row of small bed-rooms, each handsomely furnished, which those passengers can have who desire seclusion, by paying a small additional fare.

The lower apartment is commonly used as a dining or breakfast-room.

In some boats, the wheels are propelled by two engines, which are placed on the platform which overhangs the boat at either side, each wheel being propelled by an independent engine; the wheels, in this case, acting independently of each other, and without a common shaft or axle. This leaves the entire space in the boat, from stem to stern, free from machinery. It is impossible to describe the magnificent *coup d'œil* which is presented by the immense apparent length when the communication between them is thrown open. Some of these boats, as has been already stated, are upwards of three hundred feet long, and the uninterrupted length of the saloons corresponds with this.

This arrangement of machinery is attended with some practical advantages, one of which is a facility of turning, as the wheels, acting independently of each other, may be driven in opposite directions, one propelling forwards and the other backwards, so that the boat may be made to turn, as it were, on its centre. Although, from the great width of the Hudson, no great difficulty is encountered in turning the longest boat, yet cases occur in which this power of revolution is found extremely advantageous.

Another advantage of this system is, that when one of the two engines becomes accidentally disabled, the boat can be propelled by the other.

The general appearance of the Hudson steamers is represented in the annexed engraving of the "Iron Witch."

No spectacle can be more remarkable than that which the Hudson presents for several miles above New York. The skill with which these enormous vessels, measuring from three to four hundred feet in length, are made to thread their way through the crowd of shipping, of every description, moving over the face

of this spacious river, and the rare occurrence of accidents from collision, are truly admirable. In a dark night these boats run at the top of their speed through fleets of sailing vessels. The bells through which the steersman speaks to the engineer scarcely ever cease. Of these bells there are several of different tones, indicating the different operations which the engineer is commanded to make, such as stopping, starting, reversing, slackening, accelerating, &c. At the slightest tap of one of these bells, these enormous engines are stopped, or started, or reversed by the engineer, as though they were the plaything of a child. These vessels, proceeding at sixteen or eighteen miles an hour, are propelled among the crowded shipping with so much skill as almost to graze the sides, bows, or sterns of the vessels among which they pass.

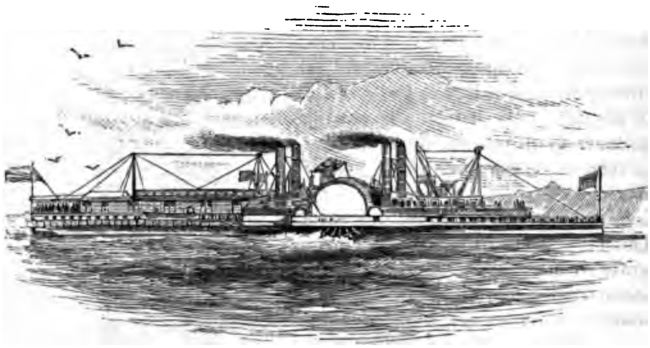
The difficulty attending the evolutions by a vessel such as the New World, for example, one hundred and twenty-five yards long and twelve yards wide, may be easily imagined; and the promptitude and certainty with which an engine whose pistons are seventy-six inches in diameter, and whose stroke is five yards in length, is governed must be truly surprising.

18. The navigation of the other rivers of the Atlantic States differs in nothing from that of the Hudson and its collateral branches, except in the extent of their traffic and the magnitude and power of the steamers. The engines, in all cases, are constructed on the condensing principle; and although steam of forty or fifty pounds above the pressure of the atmosphere is frequently used, it is worked expansively, and

a good vacuum is always sustained behind the piston by means of the condenser.

19. The steam navigation of the Mississippi is conducted in a manner entirely different from that of the Hudson and the eastern rivers. Every one must be familiar with the lamentable accidents which happen from time to time, and the loss of life from explosion which continually takes place in those regions.

These accidents, instead of diminishing with the improvements of art, appear rather to have increased. Engineers, disregarding the heart-rending narratives continually published, have done literally nothing to check the evil; and it may be almost said to be a disgrace to humanity, that the legislature of the Union has not ere this interposed its authority to check abuses, which are productive of such calamities.



MISSISSIPPI STEAMBOAT.

In a Mississippi steam-boat the cabins and saloons provided for the accommodation of the passengers, though less magnificently furnished, are as spacious as those already described in the boats on the Hudson. They are, however, erected on a flooring or platform, six or eight feet above the deck of the vessel. Upon this deck, and in the space under the cabins and saloons allotted to the passengers, are placed the engines, which are of the coarsest structure. They are invariably worked with high-pressure steam without condensation; and in order to obtain that effect, which, in the boats on the Hudson, is due to the vacuum, the steam is worked at an extraordinary pressure. I have myself frequently witnessed boilers of the most inartificial construction worked with steam of the full pressure of 120 lbs. per square inch; but more recently this pressure has been increased, the ordinary working pressure

being now 150 lbs., and I am assured, on good authority, that it is not unfrequently raised to even 200 lbs. The boilers are cylindrical, of large diameter, and of the rudest kind. When returning flues are constructed in them, the space left is so small, that the slightest variation in the quantity of water they contain, or in the trim of the vessel, causes the upper flues to be uncovered, and the intense action of the furnace in this case soon renders them red-hot, when a frightful collapse is almost inevitable. The red-hot iron, no longer able to resist the intense pressure, gives way, the boiler explodes, and the scalding water is scattered in all directions, often producing more terrible effects than even the fragments of the boiler which are projected around with destructive force.

20. Another frequent cause of explosion in these boilers is the quantity of mud held in suspension in the waters of the Mississippi below the mouth of the Missouri. As the water in the boiler is evaporated, the earthy matter which it held in suspension remains behind, and accumulates in the boiler, in the bottom of which it is at length collected in a thick stratum. This produces effects similar to those which take place in marine boilers, in consequence of the deposition of salt. This earthy stratum collected within the boiler being a non-conductor, the heat proceeding from the furnace is interrupted, and, instead of being absorbed by the water, is accumulated in the boiler-plates, which it ultimately renders red-hot. Being thus softened, they give way, and the boiler bursts. The only preventive remedy of this catastrophe is, to blow the water out of the boiler from time to time, before a dangerous accumulation of mud takes place, in the same manner as marine boilers are blown out to prevent the accumulation of salt. The engine-drivers and captains, however, rarely attend to this process. They are too intent upon obtaining speed, and, to use their own phrase, "going a-head." They do not hesitate to endanger their own lives and those of the passengers, rather than allow themselves to be outrun by a rival boat.

Not only the Mississippi, but the Ohio, the Missouri, the Illinois, the Red River, and, in a word, all the tributaries of the Father of Rivers, are navigated for many thousands of miles by this description of boats, worked with the same reckless disregard of human life.

21. The magnitude and splendour of these boats is little, if at all, inferior to those of the Hudson. They are, however, constructed more with a view to the accommodation of freight, as they carry down the river large quantities of cotton and other produce, as well as passengers, to the port of New Orleans. Many of these vessels are three hundred feet and upwards in length, and are capable of carrying a thousand tons freight, and three or four

hundred deck passengers, besides the cabin passengers. The traffic in goods and passengers of the entire extent of the immense valley of the Mississippi is carried by these vessels, except that portion which is floated down by the stream in a species of raft called flat-boats.

22. This line of steam-navigation is continued up the Mississippi, branching east and west along its great tributaries. The Ohio carries it eastwards as far as Pittsburgh, in Pennsylvania. A canal connects the Ohio at Cincinnati with Lake Erie. The navigation of the Upper Mississippi is continued by the Illinois river to a port near Lake Michigan, with which it is connected by a canal extending to Chicago, on the western shore of that lake. Here commences the great chain of lake steam-navigation, which extends across the northern division of the States, traversing Lakes Michigan, Huron, Erie, and Ontario, and being continued along the St. Lawrence, to Montreal and Quebec. The lakes are connected by canals.

By the Erie canal, connecting the lake of that name with the head of the Hudson navigation at Albany, the circuit of navigation round the United States is completed.

LOCOMOTION BY RIVER AND RAILWAY

IN THE UNITED STATES.

CHAPTER II.

1. Inland steam navigation. — 2. Table of sea-going steam-ships. — 3. Towing river steamers. —4. Water goods train.—5. Commencement of railways. — 6. Average cost of construction to 1849. — 7. Tabular statement of the railways to 1851.—8. Their distribution and general direction.—9. New England lines.—10. New York lines. 11. New York and Philadelphia.—12 Pennsylvania lines.—13. Great celerity of construction — tabular statement.—14. Extent of lines open and in progress in 1853.—15. Their distribution among the States.—16. Average cost of construction.—17. Railways in central States.—18. General summary.—19. Causes of the low comparative cost of construction.—20. Method of crossing rivers.—21. Modes of construction—rails and curves.—22. Engines.—23. Greater solidity of construction recently practised.—24. Railway carriages.—25. Expedient for passing curves.

1. NOTWITHSTANDING the facilities for coast navigation which are offered along the Atlantic shores from New York southwards, successful efforts have been directed to establish a parallel inland

communication by the Potomac and the Hudson. A line of inland steamers is established between the Potomac and New York by Chesapeake Bay, the Delaware, the Chesapeake and Delaware canal, the Delaware and Rariton canal, and the Rariton river, and by these means the same line of communication is extended to the shores of New England and Long Island Sound.

A project is introduced, and likely to be carried into effect, for enlarging the Great Erie canal, so as to admit of steamers. When this shall be effected, the entire extent of the States, from Washington, by New York, Albany, the great Northern Lakes, and the Mississippi, to New Orleans, will be surrounded by a continuous chain of inland steam-navigation. The importance of this internal communication in the event of a war must be apparent.

The form and structure of these river-steamers, as described in general terms in the last chapter, will be more easily understood

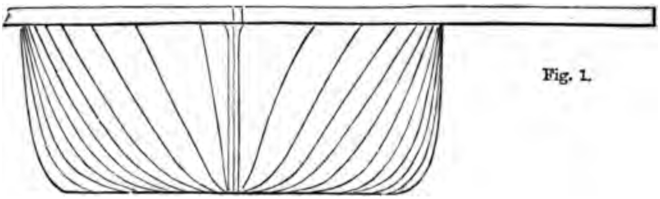
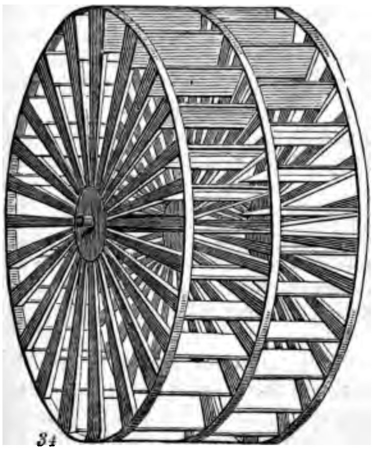


Fig. 1.

by figure 1, which represents a cross section of the hull with one-half of the platform, which is placed upon it, and which supports the upper cabins and saloons. This hull is constructed with a perfectly flat bottom and perpendicular sides, and is rounded at the angles. At the bow or cutwater they are made very sharp.

Fig. 2.



The split paddle-wheel, which until very lately was exclusively used in these boats, is represented in fig. 2, and is formed as if by the combination of two or more common paddle-wheels, placed one outside the other, on the same axle, but so that the paddle-boards of each

may have an intermediate position between those of the adjacent one, as represented in fig. 2.

The spokes, which are bolted to cast-iron flanges, are of wood. These flanges, to which they are so bolted, are keyed upon the paddle-shaft. The outer extremities of the spokes are attached to circular bands or hoops of iron, surrounding the wheel; and the paddle-boards, which are formed of hard wood, are bolted to the spokes. The wheels thus constructed, sometimes consist of three, and not unfrequently four, independent circles of paddle-boards, placed one beside the other, and so adjusted in their position that the boards of no two divisions shall correspond.

2. Although the subject of this tract is limited to inland transport, it will not be without interest to exhibit here some particulars of the progress made in the United States in sea steam-navigation. With this view we have given, in the following table, (p. 36), the dimensions and power of some of the principal sea-going steamers which had been constructed and brought into operation at the date of the last reports accessible to us. It must, however, be always remembered, that the progress of enterprise, more especially in this department, in the United States is so rapid, that probably before these pages come into the hands of the reader many other and more magnificent vessels will have been launched.

3. The other class of steamers used for towing the commerce of the rivers corresponds to the goods trains on railways. No spectacle can be more remarkable than these locomotive machines, dragging their enormous load up the Hudson. They may be seen in the midst of this vast stream, surrounded by a cluster of twenty or thirty loaded craft of various magnitudes. Three or four tiers are lashed to them at each side, and as many more at their bow and at their stern. The steamer is almost lost to the eye in the midst of this crowd of vessels which cling around it, and the moving mass is seen to proceed up the river, no apparent agent of propulsion being visible, for the steamer and its propellers are literally buried in the midst of the cluster which clings to it and floats round and near it.

4. As this *water goods train*, for so it may be called, ascends the Hudson, it drops off its load, vessel by vessel, at the towns which it passes. One or two are left at Newburgh, another at Powkeepsie, two or three more at Hudson, one or two at Fishkill, and, in fine, the tug arrives with a residuum of some half-dozen vessels at Albany.

Name and Route of Vessel.	DIMENSIONS OF VESSEL. Length.	Beam.	Depth of Hold.	Tonnage.	ENGINE. Diam. of Cylinder.	Length of Strokes.	Number of Strokes.	PADDLE-WHEEL. Diam.	Length of Bucket.	Depth of Bucket.
	ft.	ft. in.	ft. in.		in.	ft. in.		ft. in.	ft. in.	in.
Panama, Panama and San Francisco	200	33 6	20 0	..	70	8 0	17	26 0	8 9	30
Pacific, New York and Liverpool	280	45 6	24 0	..	95	9 0	16½	35 0	11 6	34
Antarctic, ditto	280	45 6	24 0	..	96	10 0	16½	35 6	12 0	32
Washington, New York, Southampton, and Bremen	230	39 0	32 0	1750	72	10 0	12	35 0	7 6	36
Hermann, Do.	235	40 0	32 0	1850	72	10 0	12	36 0	8 0	36
Southerner, New York and Charleston	196	32 0	22 0	850	67	8 0	14	31 0	7 6	30
Northerner, Do.	206	33 0	22 0	1000	70	8 0	14	31 0	7 6	30
Cherokee, New York and Savannah	212	35 0	22 0	1250	75	8 0	14	31 0	8 0	30
Tennessee, Do.	212	35 0	22 0	1250	75	8 0	14	31 0	8 6	30
Oregon, Panama and Oregon	200	34 0	20 0	1100	70	8 0	15	26 0	9 0	30
California, Do.	200	33 0	20 0	1050	70	8 0	15	26 0	9 0	30
Franklin, New York and Havre	260	42 0	26 0	2300	94	8 0	..	34 0	12 0	30
Atlantic, New York and Liverpool	280	46 0	32 0	2800	95	9 0	..	35 0	12 0	32
United States, New York, New Orleans, and Chagres	250	40 0	34 6	..	80	9 0	16	35 0	9 0	36
Crescent City, Do.	220	34 0	17 0	..	80	9 0	16	32 0	8 0	30
Empire City, Do.	230	38 0	17 6	..	83	9 0	..	32 0	8 0	30
Georgia, Do.	260	45 0	34 6	..	90	8 0	..	36 0	10 6	30
Ohio, Do.	260	47 0	34 6	..	90	8 0	..	36 0	10 6	30
Falcon, Do., touching at Havannah	206	32 0	22 0	..	60	5 0	16	30 0	7 8	13
Powhatan	254	45 0	26 6	$2419\frac{32}{95}$	70	10 0	..	31 0	10 0	30
Susquehanna	252	45 0	26 6	$2398\frac{2}{95}$	70	10 0	..	31 0	9 6	34
Saranac	215	38 0	23 6	$1459\frac{21}{95}$	60	9 0	..	27 0	9 0	30
Government vessels.								Screw Propellers.		No. of Blades.
San Jacinto	215	38 0	23 6	..	62½	4 2	..	14 0	5 0	6
Carolinian, Philadelphia and Charleston	175	28 0	18 0	660	44	3 0	..	11 0	..	
Philadelphia, Do.	192	33 0	18 6	..	56	6 9	19	27 0	8 9	
Isabel, Charleston and Havannah	222	33 0	21 6	1115	72	8 0	16	31 0	8 0	
Republic, Baltimore and Charleston	200	30 0	18 6	800	54	6 0	..	25 6	8 9	

III. Railways.

5. The phenomena of transport so unexpectedly developed on the opening of the Liverpool and Manchester Railway, and the miracles of swift locomotion there exhibited, had no sooner been announced, than the Americans, with their usual ardour, resolved to import this great improvement; and projects of passenger railways, on the vast scale which characterises all their enterprises, were immediately set forth.

Some lines of railway in isolated positions, around coal-works and manufactories, had been, as in England, already for some years in operation. It was not, however, until after 1830 that the railway system began to assume in America the character which it had already taken in England. A few years were sufficient to bring it into practical operation in several parts of New England and in the State of New York; and, once commenced, its progress was extremely rapid.

As might naturally be expected, the chief theatre of railway enterprise is the Atlantic States. The Mississippi and its tributaries have hitherto served the purposes of commerce and intercommunication to the comparatively thinly scattered population of the Western States so efficiently, that notwithstanding the extraordinary enterprise of the people, the railway system has hitherto made comparatively small progress in these vast forest-covered plains and open prairies. Nevertheless they have not altogether escaped the operations of the engineer; and the traveller already feels the benefit, even in these remote regions, of the new art of transport. These railways consist as yet of detached and single lines, unconnected with the vast network which we shall presently notice.

To the traveller in these wild regions, the aspect of such artificial agents of transport in the midst of a country, a great portion of which is still in the state of native forest, is most remarkable, and strongly characteristic of the irrepressible spirit of enterprise of its people. Travelling in the backwoods of Mississippi, through native forests, where, till within a few years, human foot never trod, through solitudes, the silence of which was never broken, even by the red man, we have been sometimes filled with wonder to find ourselves transported by an engine constructed at Newcastle-on-Tyne, and driven by an artisan from Liverpool, at the rate of twenty miles an hour. It is not easy to describe the impression produced by the juxtaposition of these refinements of art and science with the wildness of the country, where one sees the frightened deer start from its lair at the snorting of the ponderous machine and the appearance of the snake-like train which follows it.

6. The first American railway was opened for passengers on the last day of 1829. It appears that in 1849, after an interval of just twenty years, there were in actual operation 6565 miles of railway in the States. The cost of construction and plant of this system of railways, according to official reports, was 53,386885*l.*, being at the average rate of 8129*l.* per mile.

7. We have, however, before us documents which supply data to a more recent period, and have computed from them the following table, exhibiting the number of miles of railway which were in actual operation in the United States, the capital expended in their construction and plant, and the length of the lines in process of construction, but not yet completed in 1851:—

	Railways in operation.	Cost of Construction and Plant.	Railways projected and in progress.	Cost per mile.
	Miles.	£	Miles.	£
Eastern States, including Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut	2845	23,100987	567	8120
Atlantic States, including New York, the Jerseys, Pennsylvania, Delaware, and Maryland . .	3503	27,952500	2020	7979
Southern States, including Virginia, the Carolinas, Georgia, Florida, and Alabama	2106	8,253130	1283	3919
Western States, including Mississippi, Louisiana, Texas, Tennessee, Kentucky, Ohio, Michigan, Indiana, Illinois, Missouri, Iowa, and Wisconsin	1835	7,338290	5762	3999
Totals and averages . . .	10289	66,644907	9632	6478

8. Of the total length of railways which overspread the territory of the Union, more than the half are constructed in the States of Pennsylvania, New York, and those of New England. The principal centres from which these lines of communication diverge are Boston, New York, and Philadelphia.

A considerable extent, though of less importance, diverges from Baltimore; and recently lines of communication of great length have been constructed, from Charleston in South Carolina, and from Savannah in Georgia.

9. From Boston three trunk-lines issue; the chief of which passes through the State of Massachusetts to Albany, on the Hudson. This line of railway is 200 miles in length, and appears destined to carry a considerable traffic. Its ramifications southward, through the smaller states of New England, are numerous, chiefly leading to the ports upon Long Island Sound, which communicate by steam-boats with New York. The first branch is carried from Worcester, in Massachusetts, to New London on the Sound, where it meets a short steam-ferry which communicates with Greenport, at the eastern extremity of Long Island, from which another railway, nearly fifty miles long, is carried to Brooklyn, which occupies the shore of that island immediately opposite New York, and communicates with the latter city by a steam-ferry.

Thus there is a continued railway communication from Boston to New York, interrupted only by two ferries.

Another branch of the great Massachusetts line is carried south from Springfield, through Hartford to Newhaven; and a third from Pittsfield to Bridgeport, both the latter places being on the Sound, and communicating with New York by steamboats.

The second trunk-line from Boston proceeds southwards to Providence, and thence to Stonington, from which it communicates by a ferry with the Long Island Railway. This trunk-line throws off a branch from Foxburgh to New Bedford, where it communicates by ferries with the group of islands and promontories clustered round Cape Cod.

A third trunk-line proceeds from Boston through the State of Maine.

10. Notwithstanding the speed and perfection of the steam navigation of the Hudson, a railway is constructed on the east side of that river to Albany.

From Albany an extensive line of railway communication, 323 miles in length, is carried across the entire State of New York to Buffalo, at the head of Lake Erie, with branches to some important places on the one side and on the other. This line forms the continuation of the western railway, carried from Boston to Albany, and, combined with this latter, completes the continuous railway communication from the harbour of Boston to that of Buffalo on Lake Erie, making an entire length of railway communication, from Boston to Buffalo, of 523 miles.

The branches constructed from this trunk-line are not numerous. There is one from Schenectady to Troy, on the Hudson, and another from Schenectady to Saratoga; another from Syracuse to Oswego, on Lake Ontario; and another from Buffalo to the falls of Niagara, and from thence to Lockport.

Not content with this fine line of communication to the Western Lakes, the commercial interests of New York have projected, and in part constructed, a more direct route from New York to Buffalo, independent of the Hudson.

The disadvantage of this river as a sole means of communication is, that, during a certain portion of the winter, all traffic upon it is suspended by frost. In this case, the line of railway communicating already from Bridgeport and Newhaven to Albany has been resorted to by travellers. However, it may be regarded as certain, that the intermediate traffic of the State of New York along the direct line of railway now in progress from that city to Buffalo, will very speedily be sufficient for the support of an independent line of railway.

The immediate environs of New York are served by several short railways, as is usual indeed in all great capitals where the railway system of transport prevails.

The line connecting that city with Haarlem is analogous in many respects to the Greenwich and Blackwall lines at London, and the Versailles and St. Germain lines at Paris. It is supported by a like description of traffic. The New York line, however, has this peculiarity, that it is conducted through the streets of the capital upon their natural level, without either cutting, tunnel, or embankment. The carriages, on entering the town, are drawn by horses, four horses being allowed to each coach; each coach carrying from sixty to eighty persons, and being constructed like the railway coaches in general in the United States.

The rails along the streets are laid down in a manner similar to that which is customary at places where lines of railway in England cross turnpike roads on a level. The surface of the rail is flush with the pavement, and a cavity is left for the flange to sink in.

Other short railways, from New York to Paterson, Morristown, and Somerville, require no particular note.

11. The great line of railway already described, from Boston to New York, is continued southwards from that capital to Philadelphia. There are here two rival lines; one of which, commencing from Jersey city on the Hudson, opposite the southern part of New York, is carried to Bordentown, on the left bank of the Delaware, whence the traffic is carried by steamboats a few miles further to Philadelphia. The rival line commences from South Amboy in New Jersey, to which the traffic is brought from New York by steamers plying on the Rarlton river, which separates New Jersey from Staten Island. From Amboy, the railway is continued to Camden, on the left bank of the Delaware, opposite Philadelphia.

By far the greater part of the traffic between New York and Philadelphia is carried by the former line.

12. Philadelphia is the next great centre from which railways diverge. One line is carried westward through the state of Pennsylvania, passing through Reading, and terminating at Pottsville, in the midst of the great Pennsylvanian coal-field. There it connects with a network of small railways, serving the coal and iron mines of this locality. This line of railway is a descending line towards Philadelphia, and serves the purposes of the mining districts better than a level. The loaded trains descend usually with but little effort to the moving power, while the empty waggons are drawn back.

The passenger traffic is chiefly between Reading and Philadelphia.

Another line of railway is carried westward through the state of Pennsylvania, passing through Lancaster, Harrisburg, the seat of the legislature, Carlisle, and Chambersburg, where it approaches the Baltimore and Ohio Railway. The length of this railway from Philadelphia to Chambersburg is 154 miles. The former, to Pottsville and Mount Carbon, is 108 miles, the section to Reading being 64.

13. The rate at which this prodigious extent of public works has been executed will appear by the following table:—

Year.	Miles in operation.
1830	167
1832	213
1835	787
1840	2380
1845	3659
1846	4144
1847	4249
1848	5258
1849	7000
1850	8797
1851	10289

14. It appears from returns still more recent that on the 1st of January, 1853, the number of miles of railway in operation was 13315, and the number of miles in process of construction was 12029; so that in the two years ending the first of January, 1853, a total extent of railway measuring 3026 miles was brought under traffic, and the construction of 2397 miles of new railway was commenced.

15. The proportion in which this enormous extent of overland communication is distributed among the confederated States, and the proportion of its extent in each State to the superficial area and to the population, are exhibited in the following table:—

TABLE showing the Area, Population, Length of Railway, and the Ratio of the Railway to the Area and Population in each of the States of the American Union in 1853.

STATES.	AREA SQ. MILES.	POPULATION.	MILES OF RAILWAY.			MILES PER 100 SQUARE MILES OF SURFACE.			MILES PER 1000 INHABITANTS.		
			In operation.	In progress.	Total.	In operation.	In progress.	Total.	In operation.	In progress.	Total.
Maine	30280	583188	395	111	506	1·30	0·67	1·67	0·68	0·19	0·87
New Hampshire	9000	317964	500	42	542	5·55	0·47	6·02	1·57	0·13	1·70
Vermont	10212	314120	439	..	439	4·30	..	4·30	1·40	..	1·40
Massachusetts	7800	994499	1140	66	1206	14·61	0·85	15·46	1·15	0·07	1·22
Rhode Island	1306	147544	50	32	82	3·85	2·46	6·31	0·34	0·22	0·56
Connecticut	4674	370791	630	198	828	13·48	4·24	17·73	1·70	0·53	2·23
New York	46000	3,097349	2150	1004	3154	4·67	2·18	6·85	0·69	0·32	1·01
New Jersey	8320	480553	254	85	339	3·06	1·00	4·06	0·53	0·18	0·71
Pennsylvania	46000	2,311786	1211	914	2125	2·63	2·00	4·63	0·52	0·40	0·92
Delaware	2120	91535	16	11	27	0·76	0·50	1·26	0·17	0·12	0·29
Maryland	9356	583035	521	..	521	0·56	..	0·56	0·89	..	0·89
Virginia	6352	1,421661	624	610	1234	9·82	9·60	19·42	0·44	0·43	0·87
North Carolina	45000	868903	249	248	497	0·55	0·55	1·10	0·29	0·29	0·58
South Carolina	24500	668507	599	296	895	2·45	1·21	3·66	0·90	0·44	1·34
Georgia	58000	905999	857	203	1060	1·48	0·35	1·83	0·95	0·22	1·17
Florida	59268	87401	23	..	23	0·04	..	0·04	0·26	..	0·26
Alabama	50722	771671	236	666½	902½	0·47	1·31	1·78	0·31	0·86	1·17
Mississippi	47156	600555	95	875	970	0·20	1·86	2·06	0·16	1·46	1·62
Louisiana	46431	517739	63	200	263	0·14	0·43	0·57	0·12	0·39	0·51
Texas	237321	212592	32	..	32	0·01	..	0·01	0·15	..	0·15
Tennessee	45608	1,002625	185	509½	694½	0·41	1·12	1·53	0·18	0·51	0·69
Kentucky	37680	982405	94	659	753	0·25	1·75	2·00	0·09	0·67	0·76
Ohio	39964	1,980408	1418	1736	3154	3·54	4·34	7·88	0·72	0·88	1·60
Michigan	56243	397654	427	..	427	0·76	..	0·76	1·07	..	1·07
Indiana	33869	988415	755	979	1734	2·23	2·89	5·12	0·76	0·99	1·75
Illinois	55405	851470	296	1662	1958	0·53	3·00	3·53	0·35	1·95	2·30
Missouri	67380	682033	..	515	515	..	0·77	0·77	..	0·76	0·76
Wisconsin	53924	305091	56	417	473	0·10	0·77	0·87	0·18	1·37	1·55
Total	1,139891	22,587493	13315	12039	25354	77·75	44·02	121·77	16·57	13·38	29·95

It must be admitted that the results here exhibited present a somewhat astonishing spectacle. It appears from this statement that in 1853 there were in actual operation in the United States 13315 miles of railway, and 12029 projected and in process of execution. So that when a few years more shall have rolled away, this extraordinary people will actually have above 25000 miles of iron road in operation.

16. It results from the above, compared with the previous report, that the average cost of construction has been diminished as the operations progressed. The average cost of construction of the 6500 miles of railway in operation in 1849 was 8129*l.* per mile, whereas it appears from the preceding table that the actual cost of 10289 miles, in operation in 1851, has been at the average rate of 6478*l.* per mile. On examining the analysis of the distribution of these railways among the States, it appears that this discordance of the two statements is apparent rather than real, and proceeds from the fact that the railways opened since 1849, being chiefly in the southern and western States, are cheaply constructed lines, in which the landed proprietors have given to a great extent their gratuitous co-operation, and in which the plant and working stock is of very small amount, so that their average cost per mile is a little under 4000*l.* It is also worthy of observation that the distribution of this network of railways is extremely unequal, not only in quantity, but in its capability, as indicated by its expense of construction. Thus, in the populous and wealthy States of Massachusetts, New Jersey, and New York, the proportion of railways to surface is considerable, while in the southern and western States it is trifling.

17. The States of Ohio, Indiana, and Illinois, which form the great highway along which the vast tide of western emigration flows, have, within the last few years, been making extraordinary exertions to complete a system of internal railway communication; and, before ten years shall have elapsed, their extensive territory will be literally overspread with a network of railways and canals.

18. A glance at any recent map of the internal communications of the United States will fill any reflecting observer with astonishment at the enterprise of this extraordinary people. A line of railway, already 1200 miles in length, and which is incessantly increasing, stretches along the Atlantic coast. There are besides not less than eight great trunk-lines extending from the seaboard to the interior:—

	Miles.
1. Portland (Maine) to Montreal, communicating with the St. Lawrence and Ottowa rivers	300
2. Boston to Ogdensburg, where the St. Lawrence issues from Lake Ontario	400
3. Boston to Buffalo on Lake Erie	600

	Miles.
4. New York to Lake Erie	400
5. Philadelphia to Pittsburgh on the Ohio	400
6. Baltimore to the Ohio	350
7. Charleston, South Carolina, to Chatianoogy, in Tennessee	350
8. Savannah, Georgia, to Decatur, Georgia, and Montgomery, on the Alabama	500

There are also in progress of construction several detached lines of railway along the southern shores of the great lakes, intended to connect together the numerous cross-lines which traverse that country, and so to form an unbroken system of railway communication with the interior. An extensive line commencing at Galena, on the Upper Mississippi, in the heart of the mining region, crosses the state of Illinois, and passing Chicago, skirts the southern shore of Lake Michigan. This line is complete and under traffic. From Michigan city it crosses the State of that name, arriving at Sandusky, on the southern shore of Lake Erie. From Sandusky this vast artery, following the shore of the lake, arrives at Dunkirk, where it unites with several great trunk-lines, which, traversing the States of New York and Pennsylvania, communicate with the seaboard at Baltimore, Philadelphia, and New York. The extent of this line, running west and east from the Mississippi to the Atlantic, is not less than 1800 miles.

19. When it is considered that the railways in this country have cost upon an average about 40000*l.* per mile, the comparatively low cost of the American railways will doubtless appear extraordinary.

This circumstance, however, is explained partly by the general character of the country, partly by the mode of constructing the railways, and partly by the manner of working them. With certain exceptions, few in number, the tract of country over which these lines are carried is nearly a dead level. Of earthwork there is but little; of works of art, such as viaducts and tunnels, commonly none. Where the railways are carried over streams or rivers, bridges are constructed in a rude but substantial manner of timber supplied from the roadside forest, at no greater cost than that of hewing it. The station-houses, booking-offices, and other buildings, are likewise slight and cheaply constructed of timber. On some of the best lines in the more populous states the timber bridges are constructed with stone pillars and abutments, supporting arches of trusswork, the cost of such bridges varying from 46*s.* per foot, for 60 feet span, to 6*l.* 10*s.* per foot for 200 feet span, for a single line, the cost on a double line being 50 per cent. more.

20. When the railways strike the course of rivers, such as the Hudson, Delaware, or Susquehanna—too wide to be crossed by bridges—the traffic is carried by steam-ferries. The management of these ferries is deserving of notice. It is generally so

arranged that the time of crossing them corresponds with a meal of the passengers. A platform is constructed level with the line of railway, and carried to the water's edge. Upon this platform rails are laid, by which the waggons which bear the passengers' luggage and other matters of light and rapid transport are rolled directly upon the upper deck of the ferry-boat, the passengers meanwhile going under a covered way to the lower deck. The whole operation is accomplished in five minutes. While the boat is crossing the spacious river, the passengers are supplied with their breakfast, dinner, or supper, as the case may be. On arriving at the opposite bank the upper deck comes in contact with a like platform, bearing a railway, upon which the luggage waggons are rolled; the passengers ascend, as they descended, under a covered way, and, resuming their places in the railway carriages, the train proceeds.

21. The prudent Americans have availed themselves of other sources of economy, by adopting a mode of construction adapted to the expected traffic. Formed to carry a limited commerce, the railways are frequently single lines, sidings being provided at convenient situations. Collision is impossible, for the first train which arrives at a siding must enter it, and remain there until the following train arrives. This arrangement would be attended with inconvenience with a crowded traffic like that of many lines on the English railways, but even on the principal American lines the trains seldom pass in each direction more than twice a day, and their time and place of meeting is perfectly regulated. In the structure of the roads, also, principles have been adopted which have been attended with great economy compared with the English lines. The engineers, for example, do not impose on themselves the difficult and expensive condition of excluding all curves but those of large radius, and all gradients exceeding a certain small limit of steepness. Curves of 500 feet radius, and even less, are frequent, and acclivities rising at the rate of 1 foot in 100 are considered a moderate ascent, while there are not less than fifty lines laid down with gradients varying from 1 in 100 to 1 in 75; nevertheless, these lines are worked with facility by locomotives, without the expedient of assistant or stationary engines. The consequences of this have been to reduce in an immense proportion the cost of earthwork, bridges, and viaducts, even in parts of the country where the character of the surface is least favourable. But the chief source of economy has arisen from the structure of the line itself. In many cases where the traffic is lightest, the rails consist of flat bars of iron, two-and-a-half inches broad and six-tenths of an inch thick, nailed and spiked to planks of timber laid longitudinally on the road in parallel lines, so as to form what are called continuous bearings. Some of the most profitable American

railways, and those of which the maintenance has proved least expensive, have been constructed in this manner. The road structure, however, varies according to the traffic. Rails are sometimes laid weighing only from 25 lb. to 30 lb. per yard. In some cases of great traffic they are supported on transverse sleepers of wood, like the European railways; but in consequence of the comparative cheapness of wood and the high price of iron, the strength necessary for the road is mostly obtained by reducing the distance between the sleepers, so as to supersede the necessity of giving greater weight to the rails.

22. The same observance of the principles of economy is maintained with regard to their locomotive stock. The engines are strongly built, safe, and powerful, but are destitute of much of that elegance of exterior and beauty of workmanship which have excited so much admiration in the machines exhibited in the Crystal Palace. The fuel is generally wood, but on certain lines near the coal districts coal is used. The use of coke is nowhere resorted to. Its expense would make it inadmissible, and in a country so thinly inhabited, the smoke proceeding from coal is not objected to. The ordinary speed, stoppages included, is from fourteen to sixteen miles an hour. Independently of other considerations, the light structure of many of the roads would not allow a greater velocity without danger; nevertheless, we have frequently travelled on some of the better constructed lines at the ordinary speed of the English railways, say thirty miles an hour and upwards.

Of late years, however, many exceptions to this system of economical construction are presented. The competition for goods traffic which has been recently produced by the great and rapid extension of railway communication has induced the companies to impose a more strict limit on the gradients and curves, and the engineer is often restricted in laying out the lines to gradients not exceeding forty feet per mile, and curves not less than 2000 feet radius.

23. The lines are also more generally now built with greater solidity. The flat bar rail is fast giving way to rails of the more durable form, weighing from 40 lb. to 60 lb. per yard. On the Camden and Amboy roads, rails have lately been laid down, having a depth of not less than seven inches, and weighing 90 lb. per yard.

Within the last few years, also, more attention has been given to the style of the engines. They still continue generally light compared with the English locomotives, but the working machinery vies with that of the river boats in beauty of workmanship, and the engine is often even covered with a profusion of superfluous ornament.

On the railways of the Northern and Eastern States, the platform

on which the engine-driver stands is now invariably surrounded and covered so as to shelter the engine-driver from the inclemency of the weather, from the cold, wind, and snow in winter, and the scorching rays of the sun in summer. This covering is glazed at the front and the sides, so as to enable the driver to see the line before him, and at either side, and to prevent, at the same time, the blinding effect of rain, snow, or sleet. He is thus always enabled to act with promptitude and energy in case of any accident or emergency.

24. All passenger-carriages on these lines, which make long trips of above twelve hours, are furnished at one extremity with a saloon for ladies only, supplied with sofas, chairs, and all the necessary comforts and conveniences.

The form and structure of the carriages is a source of considerable economy in the working of the lines. The passenger carriages are not distinguished, as in Europe, by different modes of providing for the ease and comfort of the traveller. There are no first, second, and third classes. All are first class, or rather all are of the same class. The carriage consists of a long body like that of a London omnibus, but much wider, and twice or thrice the length. The doors of exit and entrance are at each end; a line of windows being placed at each side, similar exactly to those of an omnibus. Along the centre of this species of caravan is an alley or passage, just wide enough to allow one person to walk from end to end. On either side of this alley are seats for the passengers, extending crossways. Each seat accommodates two persons; four sitting in each row, two at each side of the alley. There are from fifteen to twenty of these seats, so that the carriage accommodates from sixty to eighty passengers. In cold weather, a small stove is placed near the centre of the carriage, the smoke-pipe of which passes out through the roof; and a good lamp is placed at each end for illumination during the night. The vehicle is thus perfectly lighted and warmed. The seats are cushioned; and their backs, consisting of a simple padded board, about six inches broad, are so supported that the passenger may at his pleasure turn them either way, so as to turn his face or his back to the engine. For the convenience of ladies who travel unaccompanied by gentlemen, or who otherwise desire to be apart, a small room, appropriately furnished, is sometimes attached at the end of the carriage, admission to which is forbidden to gentlemen.

25. It will occur at once to the engineer, that vehicles of such extraordinary length would require a railway absolutely straight; it would be impossible to move them through any portion of a line which has sensible curvature. Curves which would be altogether inadmissible on any European line are nevertheless admitted in the construction of American railways without difficulty or hesi-

tation, and through these the vehicles just described move with the utmost facility. This is accomplished by a simple and effectual arrangement. Each end of this oblong caravan is supported on a small four-wheeled railway truck, on which it rests on a pivot; exactly similar to the expedient by which the forewheels of a carriage sustain the perch. These railway carriages have in fact two perches, one at each end; but instead of resting on two wheels, each of them rests on four. The vehicle has therefore the facility of changing the direction of its motion at each end; and in moving through a curve, one of the trucks will be in one part of the curve while the other is at another,—the length of the body of the carriage forming the *chord* of the intermediate arc! For the purposes they are designed to answer, these carriages present many advantages. The simplicity of the structure renders the expense of their construction incomparably less than that of any class of carriage on an European railway. But a still greater source of saving is apparent in their operation. The proportion of the dead weight to the profitable load is far less than in the first or second-class carriages, or even than in the third-class on the English railways. It is quite true that these carriages do not offer to the wealthy passenger all the luxurious accommodation which he finds in our best first-class carriages; but they afford every necessary convenience and comfort.

AMERICAN RAILWAY CARRIAGE.—EXTERIOR.

AMERICAN RAILWAY CARRIAGE.—INTERIOR.

LOCOMOTION BY RIVER AND RAILWAY

IN THE UNITED STATES.

CHAPTER III.

1. Railways carried to centre of cities—Mode of turning corners of streets. —2. Accidents rare.—3. Philadelphia and Pittsburgh line.—4. Extent and returns of railways.—5. Traffic returns.—6. Western lines —Transport of agricultural produce.—7. Prodigious rapidity of progress.—8. Extent of common roads.—9. Railways chiefly single lines.—10. Organisation of companies and acts of incorporation.— 11. Extent of railways in proportion to population.—12. Great advantages of facility of inland transport in the United States.—13. Passengers not classed.—14. Recent report on the financial condition of the United States railways.—15. Table of traffic returns on New England lines.—16. Cuban railways.—17. Recapitulation.

1. In several of the principal American cities, the railways are continued to the very centre of the town, following the windings of the streets, and turning without difficulty the sharpest corners. The locomotive station is, however, always in the suburbs. Having arrived there, the engine is detached from the train, and

horses are yoked to the carriages, by which they are drawn to the passenger depôt, usually established at some central situation. Four horses are attached to each of these oblong carriages. The sharp curves at the corners of the streets are turned, by causing the outer wheels of the trucks to run upon their flanges, so that they become (while passing round the curve) virtually larger wheels than the inner ones. I have seen, by this means, the longest railway carriages enter the depôts in Philadelphia, Baltimore, and New York, with as much precision and facility as was exhibited by the coaches that used to enter the gateway of the Golden Cross or the Saracen's Head.

2. Notwithstanding the apparently feeble and unsubstantial structure of many of the lines, accidents to passenger trains are scarcely ever heard of. It appears by returns now before us that of 9,355474 passengers booked in 1850 on the crowded railways of Massachusetts, each passenger making an average trip of eighteen miles, there were only fifteen who sustained accidents fatal to life or limb. It follows from this, that when a passenger travels one mile on these railways, the chances against an accident producing personal injury, even of the slightest kind, are 11,226568 to 1; and, of course, in a journey of 100 miles, the chances against such accident are 112266 to 1. It has been shown that the chances against accident on an English railway, under like circumstances, are 40000 to 1.* The American railways are, therefore, safer than the English in the ratio of 112 to 40.

3. A great line of communication was established, 400 miles in length, between Philadelphia and Pittsburg, on the left bank of the Ohio, composed partly of railway and partly of canal. The section from Philadelphia to Colombia (eighty-two miles) is railway; the line is then continued by canal for 172 miles to Holidaysburg; it is then carried by railway thirty-seven miles to Johnstown, whence it is continued 104 miles further to Pittsburg by canal. The traffic on this mixed line of transport was conducted so as to avoid the expense and inconvenience of transhipment of goods and passengers at the successive points where the railway and canals unite. The merchandise was loaded and the passengers accommodated in the boats adapted to the canals at the depôt in Market Street, Philadelphia. These boats, which were of considerable magnitude and length, were divided into segments by partitions made transversely, and at right angles to their length, so that each boat can be, as it were, broken into three or more pieces. These several pieces were placed each on two railway trucks, which support it at its ends, a proper body being

* Museum, Vol. i., p. 168.

provided for the trucks, adapted to the form of the bottom and keel of the boat. In this manner the boat was carried in pieces, with its load, along the railway. On arriving at the canal, the pieces were united so as to form a continuous boat, which being launched, the transport is continued on the water. On arriving again at the railway, the boat was once more resolved into its segments, which, as before, were transferred to the railway trucks, and transported to the next canal station by locomotive engines. Between the depôt in Market Street and the locomotive station, situated in the suburbs of Philadelphia, the segments of the boat were drawn by horses on railways conducted through the streets. At the locomotive station the trucks were formed into a continuous train, and delivered over to the locomotive engine. As the body of the truck rests upon a pivot, under which it is supported by wheels, it is capable of revolving, and no difficulty is found in turning the shortest curves; and these enormous vehicles, with their contents of merchandise and passengers, were seen daily issuing from the gates of the depôt in Market Street, and turning with facility the corners at the entrance of each successive street.

More recently, a continuous line of railway has been completed, and is now in operation, between Philadelphia and Pittsburgh. Indeed, so rapid is the progress of improvement in the United States, that a report of the state of inland communication, as it existed a year or two ago, will be found to be full of inaccuracies as applied to the present moment.

4. By a comparison of the returns published in my work already quoted, with the more recent results already given, it will appear that within the last four years not less than 6750 miles of railway have been opened for traffic in the United States. Among these are included several of the most important lines, of which the most especially to be noticed is the great artery of railway communication extending across the State of New York to the shores of Lake Erie, the longest line which any single company has yet constructed in the United States, its length being 467 miles. The total cost of this line, including the working stock, has been 4,500000*l*. sterling, being at the average rate of 9636*l*. per mile—a rate of expense about 50 per cent. above the average cost of the American railways taken collectively. This is explained by the fact that the line itself is one constructed for a large traffic between New York and the Interior, and therefore built to meet a heavy traffic. Immediately after being opened, its average receipts have amounted to 11000*l*. per week, which gave a net profit of 6½ per cent. on the capital, the working expenses being taken at 50 per cent. of the gross receipts. One of the great lines connects New York with Albany, following the valley of the

Hudson. It will no doubt create surprise, considering the immense facility of water transport afforded by this river, that a railway should be constructed on its bank, but it must be remembered that for a considerable interval during the winter the navigation of the Hudson is suspended from the frost.

5. It is difficult to obtain authentic reports from which the movement of the traffic on the American railways can be ascertained with precision. I obtained, however, the necessary statistical data relating to nearly 1200 miles of railway in the states of New England and New York, from which I was enabled to collect all the circumstances attending the working of these lines.

It appears from calculations, the details of which will be found in my work,* that upon those railways the total average receipts per mile per annum was 4694*l.*, and that the profit per cent. of capital amounted to 8·6 per cent.

6. It appears by recent and well-authenticated returns, that the Western lines, most of which are of recent construction, and derive their revenue almost exclusively from the transport of agricultural produce, have proved even more profitable than the Eastern Railways, whose traffic is chiefly passengers. A large proportion of these Western lines paid from 7 to 10 per cent., even before they were quite completed, according to a report obtained by the "Times."† This prosperous result was obtained even from the lines which traversed uncleared districts and dense forests. The source of this advantage is the profit sure to be obtained from the transport of agricultural produce. In these districts there are no inland markets. The farmer is obliged to send his produce either to the sea-coast or to the bank of one of the great rivers, where alone markets are found. There alone are the manufacturers, and there alone the exporting merchants established. It has been proved that agricultural produce can, at least in the United States, be transported on railways at one-tenth of the expense of its carriage on common roads. In the following table (page 53) is given the comparative value of a ton of wheat and of maize at various distances from the farm-yard, the cost of its transport by each mode of conveyance being deducted from its cost at the place of production.

It appears, therefore, that the whole value of wheat is absorbed by the cost of its transport 330 miles on a common road, while 10 per cent. of its value is absorbed by its transport the same distance by railway. In like manner, while the entire value of maize is absorbed by its transport over 160 miles of common road, no more than 9¾ per cent. of its value is absorbed by transport to the same distance by railway.

* Railway Economy, chap. xvi.

† September 3, 1853.

	Transportation by Railroad.				Transportation by Ordinary Highway.			
	Wheat.		Maize.		Wheat.		Maize.	
	dols.	c.	dols.	c.	dols.	c.	dols.	c.
Value at . .	49	50	24	75	49	50	24	75
10 miles . .	49	35	24	60	48	0	23	25
20 " . .	49	20	24	45	46	50	21	75
30 " . . .	49	5	24	30	45	0	20	25
40 " . .	48	90	24	15	43	50	18	75
50 " . . .	48	75	24	0	42	0	17	25
60 " . .	48	60	23	85	40	50	15	75
70 " . . .	48	45	23	70	39	0	14	25
80 " . .	48	30	23	55	37	50	12	75
90 " . . .	48	15	23	40	36	0	11	25
100 " . .	48	0	23	25	34	50	9	75
110 " . . .	47	85	23	10	33	0	8	25
120 " . .	47	70	22	95	31	50	6	75
130 " . . .	47	55	22	80	30	0	5	25
140 " . .	47	40	22	65	28	50	3	75
150 " . . .	47	25	22	50	27	0	2	25
160 " . .	47	10	22	35	25	50	0	75
170 " . . .	46	95	22	20	24	0		
180 " . .	46	80	22	5	22	50		
190 " . . .	46	65	21	90	21	0		
200 " . .	46	50	21	75	19	50		
210 " . . .	46	35	21	60	18	0		
220 " . .	46	20	21	45	16	50		
230 "	46	5	21	30	15	0		
240 " . .	45	90	21	15	13	50		
250 " . . .	45	75	21	0	12	0		
260 " . .	45	60	20	85	10	50		
270 " . . .	45	45	20	70	9	0		
280 " . .	45	30	20	55	7	50		
290 " . . .	45	15	20	40	6	0		
300 " . .	45	0	20	25	4	50		
310 " . . .	44	85	20	10	3	0		
320 " . .	44	70	19	95	1	50		
330 " . . .	44	55	19	80	0	0		

These results are important to the holder of stock in these western lines, in so far as they demonstrate how permanent and secure must be the revenue of the western railroads. The vast bulk of the western population is agricultural, and will long continue to be so, and by far the largest proportion of the receipts of their railways will be from the transportation of freight. There is, besides, hardly a country in the world where the same amount of labour produces an equal amount of freight. These, and other reasons which will suggest themselves from the facts given, go to show how solid the basis would seem to be for the prosperity of the western roads generally, while the premium for which their

stocks are selling, and the dividends they divide, illustrate the matter by incontestable facts.

The year 1852 was the most prosperous year for the American western railroads in operation and in progress. Their increased earnings are said, upon good authority, to average an increase of 15 per cent. upon their *mileage*, and 10 per cent. upon their *cost*. This vast increase is attributed partly to abundant crops and partly to a general increase of activity in every department of business; but in that country more than in any other, the extension of the railroad system seems likely to exert a beneficial effect upon each individual railroad for itself. There is scarcely such a thing now heard of as travelling or freight transportation, except on railroads or by water. The public sees that undue importance has been hitherto attached to canals, and it is now found to be difficult, if indeed it will not ultimately prove impossible, to get the people of the State of New York to appropriate 10,000,000 dollars more for the final enlargement or completion of the canals already built in that State alone. Transportation or travel by canals is too slow—it does not suit the electric speed of the age. We may, therefore, expect in the future that little more will be done for canals, while a network of railroads seems destined inevitably to cover that continent.

7. Americans themselves can hardly imagine the railroad progress of the United States till they come to the figures of what has actually been done; much less can they comprehend their probable progress in the future. Those who have bestowed the most reflection on the subject entertain no doubt that the construction of railways in the south-west and west—that boundless granary of the world—will continue and increase with augmented ratio for a long time to come. If that vast district should be supplied with railways as Massachusetts now is, it would demand at least 100000 miles of railway! What political economist in England or in America can fail to draw an inference here in favour of Free Trade? With the superior facilities of Great Britain for manufacturing iron, and the still greater facilities of the United States for the prosecution of agriculture, who is so blind as not to see that they ought to take our iron and to pay for it in bread, unless bad and unhealthy legislation interrupt this natural order of the law of Providence? *

8. The extraordinary extent of railway constructed at so early a period in the United States has been by some ascribed to the absence of a sufficient extent of communication by common roads. Although this cause has operated to some extent in certain districts, it is by no means so general as has been supposed. In the year

* "Times," September 3, 1853.

1838, the United States mails circulated over a length of way amounting on the whole to 136218 miles, of which two-thirds were land transport, including railways as well as common roads. Of the latter there must have been about 80000 miles in operation, of which, however, a considerable portion was bridle-roads. The price of transport in the stage coaches was, upon an average, 3·25*d.* per passenger per mile, the average price by railway being about 1·47*d.* per mile.

From what has been stated above, it will be apparent that the true cause of the vast extension of railways in the United States is the immense economy and speed of transport upon them compared with transport on common roads.

9. Of the entire extent of railway constructed in the United States, by far the greater portion, as has been already explained, consists of single lines, constructed in a light and cheap manner, which in England would be regarded as merely serving temporary purposes: while, on the contrary, the entire extent of the English system consists, not only of double lines, but of railways constructed in the most solid, permanent and expensive manner, adapted to the purposes of an immense traffic. If a comparison were to be instituted at all between the two systems, its basis ought to be the capital expended, and the traffic served by them, in which case the result would be somewhat different from that obtained by the mere consideration of the length of the lines. It is not, however, the same in reference to the canals, in which it must be admitted that America far exceeds all other countries in proportion to her population.

10. The American railways have been generally constructed by joint-stock companies, which, however, the State controls much more stringently than in England. In some cases a major limit to the dividends is imposed by the statute of incorporation, in some the dividends are allowed to augment, but when they exceed a certain limit the surplus is divided with the State; in some the privilege granted to the companies is only for a limited period, in some a sort of periodical revision and restriction of the tariff is reserved to the State. Nothing can be more simple, expeditious, and cheap than the means of obtaining an act for the establishment of a railway company in America. A public meeting is held at which the project is discussed and adopted, a deputation is appointed to apply to the Legislature, which grants the Act without expense, delay, or official difficulty. The principle of competition is not brought into play as in France, nor is there any investigation as to the expediency of the project with reference to future profit or loss, as in England. No other guarantee or security is required from the company than the

payment by the shareholders of a certain amount, constituting the first call. In some States the non-payment of a call is followed by the confiscation of the previous payments, in others a fine is imposed on the shareholders, in others the share is sold, and if the produce be less than the price at which it was delivered, the surplus can be recovered from the shareholder by process of law. In all cases the Acts creating the companies fix a time within which the works must be completed, under pain of forfeiture. The traffic in shares before the definite constitution of the company is prohibited.

Although the State itself has rarely undertaken the execution of railways, it holds out, in most cases, inducements in different forms to the enterprise of companies. In some cases the State takes a great number of shares, which is generally accompanied by a loan made to the company, consisting in State stock delivered at par, which the company negotiate at its own risk. This loan is often converted into a subvention.

11. The great extent of internal communication, by railways and canals, in America, in proportion to its population, has been a general subject of admiration. The population of the United States in 1840 amounted to 17 millions, and if its rate of increase during the ten years commencing at that epoch be equal to the rate during the preceding ten years, its present population must be about 23 millions. There are, as I have stated, about 6500 miles of railway in actual operation within the territory of the Union. This, in round numbers, is at the rate of one mile of railroad for every 3200 inhabitants.

In the United Kingdom, there are in operation 5000 miles of railway, with a population of 30 millions, which is at the rate of one mile for every 6000 inhabitants.

It would therefore appear that, in proportion to the population, the length of railway communication in the United States is greater than in the United Kingdom in the proportion of 6 to 3½. The result of this calculation, however, requires considerable modification.

12 There is no country where easy and rapid means of communication are likely to produce more beneficial results than in the United States. Composed of twenty-six independent republics, having various, and in some instances opposite interests, the American confederacy would speedily be in danger of dissolution, if its population, scattered over a territory so vast, were not united by communications sufficiently rapid to produce a practical diminution of distance. In this means of intercommunication, Nature has greatly aided the efforts of art, for certainly no country in the world presents such magnificent lines of natural water communication.

To say nothing of the streams which intersect the Atlantic States, and carry an amount of inland steam navigation wholly

unexampled in Europe, we have the gigantic stream of the Mississippi, intersecting the immense valley to which it gives its name, with innumerable tributaries, navigable by steam-boats having a tonnage of first-rate ships for many thousands of miles, and traversing territories which present immense tracts of soil, of the highest degree of fertility, as well as sources of mineral wealth which are as yet unexplored.

13. On the American railways, passengers are not differently classed, or admitted at different rates of fare, as on those in Europe. There is but one class of passengers and one fare. In one or two instances, second and third-class carriages were attempted to be established, but it was found that the number of passengers availing themselves of the lower fares and inferior accommodation was so small that they were discontinued. The only distinction observable among passengers on railways is that which arises from colour. The coloured population, whether emancipated or not, are generally excluded from the vehicles provided for the whites. Such travellers are but few; and they are usually accommodated either in the luggage van or in the carriage in which the guard or conductor travels.

14. We take the following observations on the financial condition of the railways of the United States from the report already quoted from the "Times." Although it emanates evidently from a partisan, it is from an intelligent, well-informed, and honest partisan, and is well deserving of attention.

"1. In all instances the railroads of the United States have received their charters from the governments of the several States through which their routes extend. I am not aware, with a few exceptions, of an instance in which the application of a company for a charter for a railway has been refused, provided the responsibility of the applicants, or the amount of capital stock subscribed, has afforded a satisfactory guarantee for the execution of their designs. The powers and privileges conferred by these State charters are very similar to those conferred by the British Parliament. Railroad property in the United States occupies the same relations to State Governments as the property of individuals. The companies are independent in their action, and responsible to the State authorities as private citizens.

"2. I shall dwell more particularly upon the western railroads, because their history, condition, and prospects more materially concern European readers, their bonds being those now most frequently in the market. A very large number of the western railroads have obtained their charters under what are termed general railroad laws, in distinction from special statutes enacted for the incorporation of companies named within the Acts.

Within the last few years the tendency in this country has been to general rather than to special legislation. The great States (New York leading the way) have many of them enacted general laws authorising the construction and providing for the management of railways, as well as other corporations and great institutions. General railroad laws now exist in New York, Illinois, Ohio, Indiana, and Wisconsin, in all which States special charters conferring special powers are prohibited. The same principle of legislation will doubtless be adopted in other States. There are many advantages to the public in general laws, particularly as they concern railways; for monopolies are thereby rendered impossible, and the principle of *laisser faire* is adopted and carried out with the least possible interference with private rights. Under their operation, associations of men have the same right to construct railroads as to build factories or ships, and it is found by experience that each community is fully competent to regulate its own affairs.

"3. The stock and bonds of railroads are regarded as personal property, and, as such, within specific limitations, subject to taxation. No tax ever can be laid upon the bed of a road, its iron, cars, &c.; but where valuable real estate is owned for depôts, taxes may be levied. But shares and bonds can only be taxed to the holder thereof; and, of course, cannot be taxed when held abroad. In this respect, European holders of American shares and stocks have an advantage over ourselves.

"4. Companies organised under general laws cannot be dissolved without special authority from the legislature of a State; and, if the time comes that any American railway company asks for a dissolution, then, and then only, will the property of the company be distributed *pro rata* among the stockholders. I do not know of a single onerous condition or obligation laid upon an American railroad company by any State, while I am not aware that any railroad corporation has been formed in England of which the same can be said.

"5. No railroad can exist in the United States that has any right to declare dividends until it has discharged all its obligations due at the time; and all its bonds and debts of every description take precedence, and can be prosecuted and collected before the original stockholders can either receive a dividend or profit from it in any shape whatever. If there be a failure to pay its bonds or mortgages, the bondholders or mortgagees can, by a short and simple legal process, become vested with entire control over the property, and manage it on their own account. In other words, the right to apply the well-known principles of law to the relation of mortgagees and mortgagors obtain in all our railroads,

and they can be enforced by any court of equity within the judicial district. The payment of railroad bonds is generally secured by deed of trust to some known and responsible citizen of New York as trustee, with full power given in the deed to the trustee to take possession of the road, its income, franchises, personal effects, &c., in case of default, and to sell the same for cash to the highest bidder, at sixty days' notice, without the intervention of a Court of Chancery.

"6. Nearly all the bonds issued by American railways have the same general features. They are either secured by mortgage upon the property of the roads themselves, or they are common bonds for the payment of money. But they are subdivided into two classes—those which are convertible into stock at the option of the owner, to the amount on their face, whenever the holder sees fit; or they have no such condition attached. Convertible bonds have an advantage over the latter, inasmuch as they can be converted into stock so soon as that stock rises above par. This condition has been found peculiarly advantageous to many of the holders of the bonds on the western roads, since the stocks of most of these roads have gone above par as soon as they were completed.

"7. Nearly all the western railroads were projected and built for the special benefit of the people themselves in those districts through which they pass. Their sole object was to be brought nearer to a market for their produce, and many municipal bodies subscribed for stocks with no expectation that they would ever become valuable in any other way. Capital was scarce in the west, as it is in most new countries. There was a serious want of outlets to New York and navigable streams. Hence these railroads were undertaken with the expectation of general advantages to the community. But cities and counties could not create debts, or expend the money in their treasuries for such purposes, without special authorisation from the State legislatures. The object of this was to give character and legality to their acts, that they might have binding force, and also to equalise the burden of those debts over the owners of property in those sections. The charters, therefore, of almost all the western railroads authorised those cities and counties through which they passed to subscribe by a uniform mode to the stock of those roads. But invariably one safe condition was attached to this permission—that such action should also be authorised by a vote of the majority of the citizens themselves. This voluntary principle has worked admirably; because no city or county has had the right to subscribe for stock in roads until a majority of the voters thereof so decided; and thus the highest sanction of the will of the taxpayers and of law was imparted to their action. In no one instance can I

ascertain that any city or county has thus incurred a debt of more than from 2 to 5 per cent. on the taxable property of its citizens. The amount subscribed by cities and counties has ranged from 50,000 to 400,000 dollars, where the taxables would rise as high as from 4,000,000 to 16,000,000 dollars.

"8. These municipal debts thus created have been secured by all the guarantees that the State legislatures could throw around them. The cities and counties have been required to levy and collect, in case of necessity, taxes (as any and all other municipal taxes are) from their own citizens, sufficient to pay the interest, and provide a balance as a sinking fund to pay off the debt, when it should finally become due. In no instance has any western city or county hitherto neglected to do this, nor is it likely that any ever will.

"9. The bonds thus issued to railroad companies by cities and counties are guaranteed by the roads, and then sold in the market. They have all the legal force of a lien on all the property of those cities or counties, real and personal, and, if the proper authorities do not provide for the payment of the interest and principal, a *mandamus*, or an ordinary suit at law, can be issued, by which all the real and personal property of the citizens of those cities and counties can be attached and sold. Many years since the city of Bridgeport, in Connecticut, gave her bonds to a railway company for 100,000 dollars. For some reason the payment of these bonds was delayed. A holder brought a suit against the city in the State Court, and the Supreme Court decided on appeal that the individual property, real and personal, of each citizen, was liable for the debt of the city, and could be sold on execution of the decree.

"10. The operation of these laws and of this system of subscription to roads has been uniformly, I believe, beneficent. I cannot learn that there is a completed road in Ohio, for instance, that has paid less than from 10 to 14 per cent.; and, as in a great majority of instances, the cities and counties that gave their bonds have been enabled, either by converting them at their will into stock or otherwise, to sell them, and often at a large premium, thus realising large profits for thus lending their credit. The city of Cleveland, in Ohio, subscribed 400,000 dollars to two or three roads, and she is now selling that stock at a premium of from 24 to 27 dollars advance. Her taxable property since 1849 has risen from 3,000,000 to 7,000,000 dollars, while the population as well as taxable property has increased in almost the same ratio in those cities and those counties throughout the west where railroads have been built."

15. It would be extremely interesting, were it practicable, to obtain even an approximate estimate of the actual commerce in

passengers and goods on the American railways. No such general return, however, is attainable. In my work on Railway Economy, in the absence of more complete information, I have given the necessary statistical data to determine the commerce on nearly twelve hundred miles of railway in the States of New England and in that of New York, from which I was enabled to calculate all the circumstances attending the working of these lines. I have, accordingly, given these in the following table :—

Tabular Analysis of the average daily Movement of the Traffic on Twenty-eight principal Railways in the States of New England and in the State of New York during the year 1847.

	Passenger Traffic.				Goods Traffic.			
	Number booked.	Mileage.	Receipts.	Mileage of Trains.	Tons booked.	Mileage.	Receipts.	Mileage of Trains.
Albany and Schenectady	630	9,787	£ 65	136			32	62
Utica-Schenectady	733	37,600	300	406			111	360
Syracuse-Utica....	544	21,550	169	288			38	151
Auburn-Rochester	518	24,200	197	400			37	212
Tonawanda	367	13,000	92	212			23	40
Attica-Buffalo	358	9,850	61	162			19	48
Saratoga-Schenectady.	146	2,068	22	54	1730*	65,550*	4	4
Troy-Schenectady.	189	3,840	20	140			8	9
Ransseller-Saratoga.............	181	2,625	24	680			12	26
Troy and Greenbush	545	3,090	21	131			25	19
New York and Haarlem........	4,336	17,000	133	450			80	170
New York-Erie ..	326	12,400	60	246			102	191
Boston-Worcester .	1,640	39,672	180	580	775	20,450	221	459
Western	1,062	48,952	296	648	752	76,580	471	1,408
Norwich-Wor'ster.	434	8,158	67	326	249	7,858	64	204
Connecticut River.	650	6,454	42	203	122	2,210	28	64
Pittsfield-N. Adam	98	11,048	9	45	29	469	6	31
Boston-Providence	1,338	19,680	133	464	240	5,310	69	143
Tarenton	297	3,234	20	60	83	910	10	19
New Bedford......	268	4,460	40	173	53	930	13	53
Stoughton Branch.	46	482	3	11	22	238	3	4
Lowell	1,328	26,050	120	452	770	10,450	139	194
Nashua	618	8,540	41	81	414	6,130	49	55
Boston-Maine	1,995	34,500	189	625	330	9,880	106	200
Fitchburg	1,342	21,920	98	434	670	14,230	119	192
Eastern	2,240	34,910	203	557	112	3,190	30	93
Old Colony	1,068	13,420	73	288	117	2,048	24	77
Fall River........	474	8,860	46	219	79	1,718	18	72
	23,771	447,350	2,724	8,471	6,547	246,151	1,861	4,560

* The reports do not supply the tonnage and mileage of these railways separately, and the above numbers are estimated by analogy with the other American railways.

	Miles.
Total length of the above railways in the State of New York	490
,, ,, ,, States of New England	670
Total	1160

	£
Average cost of construction and stock per mile in the State of New York	7,010
,, ,, ,, States of New England	10,800
General average . . .	9,200

	Receipts.	Expenses.	Profits.
Total average receipts, expenses, and profits per day in the State of New York .	1654	684	970
,, ,, States of New England	3040	1505	1535
Totals	4694	2189	2505

	Per Mile of Railway per day.	Per Mile run by Trains.	Per Cent. per Annum on Capital.
Receipts . . .	4·05	7 5	16·1
Expenses . . .	1·89	3 5½	7·5
Profits . .	2·16	2 11½	8·6
Expense per cent. of receipts . . .			46·8

Average receipts per passenger booked . .	27·0*d.*
Average distance travelled per passenger . . .	18·2 miles.
Average receipts per passenger per mile . .	1·47*d.*
Average number of passengers per train . . .	54·0
Total average receipts per passenger train per mile	7*s.*
Average receipts per ton of goods booked . .	5*s.* 8½*d.*
Average distance carried per ton	38·0 miles.
Average receipts per ton per mile	1·8*d.*
Average number of tons per train . . .	54·5
Total average receipts per goods train per mile .	8·2*s.*

The railways, of the traffic of which I have here given a synopsis, include the most active and profitable enterprises of this kind in the United States. We cannot, therefore, infer from the results obtained the corresponding movement on the remaining lines. It appears that of the entire system of American railways, the dividends, exclusive of those contained in the preceding analysis, are in general small, and in many instances nothing. It is therefore probable that, in the aggregate, the average profits on the total amount of capital invested in the railways do not exceed, if they equal, the average profits obtained on the capital invested in English railways.

16. Although Cuba is not yet *annexed* to the United States, its local proximity here suggests some notice of a line of railway which traverses that island, forming a communication between the

city of Havannah and the centre of the island. This is an excellently constructed road, and capitally worked by British engines, British engineers, and British coals. The impressions produced in passing along this line of railway, though different from those already noticed in the forests of the far west, is not less remarkable. We are here transported at thirty miles an hour by an engine from Newcastle, driven by an engineer from Manchester, and propelled by fuel from Liverpool, through fields yellow with pine-apples, through groves of plantain and cocoa-nut, and along roads inclosed by hedge-rows of ripe oranges.

17. To what extent this extraordinary rapidity of advancement made by the United States in its inland communications is observable in other departments will be seen by the following table, exhibiting a comparative statement of those data, derived from official sources, which indicate the social and commercial condition of a people through a period which forms but a small stage in the life of a nation:—

	1793.	1851.
Population	3,939,325	24,267,488
Imports	£6,739,130	£38,723,545
Exports	£5,675,869	£32,367,000
Tonnage	520,704	3,535,451
Lighthouses, beacons, and lightships	7	373
Cost of their maintenance . .	£2,600	£115,000
Revenue	£1,230,000	£9,516,000
National expenditure	£1,637,000	£8,555,000
Post-offices	209	21,551
Post roads (miles)	5,642	178,670
Revenues of Post-office . . .	£22,800	£1,207,000
Expenses of Post-office . . .	£15,650	£1,130,000
Mileage of mails	—	46,541,423
Canals (miles)	—	5,000
Railways (miles)	—	10,287
Electric telegraph (miles) . . .	—	15,000
Public libraries (volumes) . .	75,000	2,201,623
School libraries (volumes) . . .	—	2,000,000

If they were not founded on the most incontestable statistical data, the results assigned to the above table would appear to belong to fable rather than history. In an interval of little more than half a century it appears that this extraordinary people have increased above 500 per cent. in numbers; their national revenue has augmented nearly 700 per cent., while their public expenditure has increased little more than 400 per cent. The prodigious extension of their commerce is indicated by an increase of nearly 500 per cent. in their imports and exports, and 600 per cent. in

their shipping. The increased activity of their internal communications is expounded by the number of their post-offices, which has been increased more than a hundred fold; the extent of their post-roads, which has been increased thirty-two fold; and the cost of their post-office, which has been augmented in a seventy-two fold ratio. The augmentation of the machinery of public instruction is indicated by the extent of their public libraries, which have increased in a thirty-one fold ratio, and by the creation of school libraries, amounting to 2,000,000 volumes. They have completed a system of canal navigation, which, placed in a continuous line, would extend from London to Calcutta; and a system of railways which, continuously extended, would stretch from London to Van Diemen's Land, and have provided locomotive machinery by which that distance would be travelled over in three weeks, at the cost of 1½*d.* per mile. They have created a system of inland navigation, the aggregate tonnage of which is probably not inferior in amount to the collective inland tonnage of all the other countries in the world; and they possess many hundreds of river steamers, which impart to the roads of water the marvellous celerity of roads of iron. They have, in fine, constructed lines of electric telegraph which, laid continuously, would extend over a space longer by 3000 miles than the distance from the north to the south pole, and have provided apparatus of transmission by which a message of three hundred words despatched under such circumstances from the north pole might be delivered *in writing* at the south pole in one minute, and by which, consequently, an answer of equal length might be sent back to the north pole in an equal interval.

These are social and commercial phenomena for which it would be vain to seek a parallel in the past history of the human race.*

* Lardner on the Great Exhibition, p. 251.

TELESCOPIC VIEW OF ENCKE'S COMET, BY STRUVE, AS IT APPEARED ON NOV. 7, 1828.

COMETARY INFLUENCES.

CHAPTER I.

1. Popular tendency to connect terrestrial events with celestial phenomena. —2. Popular opinions as to influences of Comets.—3. Explanation of Comets, their nature—attractions—their shape, volume, and mass—tails—density—non-luminous.—4. Question discussed as to a Comet encountering the Earth, and the result—Comet of 1832, of 1805—Probabilities of such an occurrence.—5. Question discussed as to the temperature of the seasons being affected by Comets.—6. Question discussed as to the Earth passing through the tail of a Comet, and the probable consequences.—7. Suppositions adopted by some authors as to Comets producing epidemic diseases—Comet of 1680—Great Plague of London—Comet of 1668 alleged to have produced a remarkable epidemic among cats in Westphalia.—8. Comet of 1746—Earthquakes of Lima and Callao ascribed to it.—9. Various influences ascribed to particular Comets—Earthquakes—Plagues—the success of the Turks under Mahommed II.

1. In all ages, and among all people, a tendency has prevailed to connect terrestrial events with celestial phenomena. Popular opinion in such cases seeks no reason for its foundation. No attempt to establish any such relation as that of cause and effect

is thought of. The appearance presented in the heavens, whatever it be, is simply regarded as the harbinger, precursor, or presage of the terrestrial events which are supposed to accompany or to succeed it. When the celestial phenomena thus regarded are from their nature periodical and recurring, as in the case of the succession of lunar phases, some attempt is made to generalise the imputed effects, and to reduce them to rules. In the case, however, of celestial appearances, which are occasional and extraordinary, and which have no discovered periodicity, no such general rule can be established. In such cases mankind is, however, not less prompt and confident in ascribing to their appearance any extraordinary events whatever which may have taken place simultaneously with or immediately after them.

2. Among this latter class of occasional phenomena comets hold a conspicuous place, and have at all times and in all countries operated powerfully on the superstitious feelings of mankind. These bodies, scarcely less in modern and enlightened times than in the more remote and darker ages, and scarcely less among the most civilised than among the most barbarous nations, have been regarded with feelings of inexpressible awe and terror, and looked upon as the harbingers and precursors of the most extraordinary diversity of effects, physical, physiological, social, and political. To them are unhesitatingly ascribed extraordinary extremes of heat and cold of the seasons, whether general or local; storms of snow, hail, wind and rain, hurricanes, earthquakes, volcanic eruptions, floods, droughts, and fogs; every form and character of epidemic malady, whether affecting the human race or the lower animals, the state of the harvest and the vintage, whether it be that of scarcity or abundance, of good or bad quality; the fruitfulness of women, the births and deaths of extraordinary men, the march of armies, and the fall of empires.

3. Without insisting, as we very well might, upon the manifest absurdity and glaring contradiction and inconsistency of most of these supposed influences or effects, let us first explain briefly, so far as observation has informed us, what the bodies are, to which effects so diverse and extraordinary are imputed. Such an explanation will of itself go far to dispel most of these errors. We shall also compare the effects ascribed to the presence and influence of comets with the dates of the appearances of these bodies, their number, magnitude, and proximity, so as to ascertain whether any such correspondence has really existed as has been assumed.

Comets are not, as was anciently supposed, atmospheric phenomena. They move through the regions of space occupied by the planets. Most of them come into the solar system from parts of

the universe which extend to enormous distances beyond its limits, and after passing among the planets and approaching more or less near to the sun, they again disappear, issuing to distances not less remote.

The number of those which have been actually seen, and whose appearances have been recorded, amounts to many hundreds. But when the chances against these bodies being visible during the intervals, often very brief, of their passage through the solar system, the vast numbers of them which can only be seen by the aid of telescopes, the frequency of their position being such that they are only above the horizon of observers during the day, or that they can only be within the range of vision in latitudes where no observers are found, are severally considered, it will be evident that the number of comets actually seen must form a very small fraction of the total number which have visited our system.

Reasoning upon the common principles of the doctrine of probabilities, Arago has shown that the number of comets which have passed through the system cannot be less than three and a half millions, but that it is possible that they may amount to twice that number. Even with the limited information respecting these bodies, which was attainable by Kepler, that astronomer declared that "there are more comets in space than fishes in the ocean."

Of the many hundreds whose appearances have been recorded, dating from the earliest historical notices of these bodies, about two hundred have been observed during the short intervals of their appearance, with sufficient precision to enable astronomers to calculate the paths or orbits in which they moved. These calculations have led to a result of the highest importance, inasmuch as they have established demonstratively the fact that these comets are masses of ponderable matter. The forms of their orbits prove this. It has been shown by Newton that if a body move in a certain form of curve, called by geometers a conic section, having a point called its focus at the centre of the sun, it must be subject to the attraction of the sun's gravitation, and it must reciprocally attract the sun. Now these comets have been ascertained by observation to move in these very curves, the sun being in their common focus. Hence they and the sun mutually attract each other, according to the universal law of gravitation. They are, therefore, masses of ponderable matter.

But these masses are not only attracted by the sun but by the planets, primary and secondary, near to which they pass, and they are ascertained to deviate considerably, by reason of such attractions, from the paths they would follow if subject only to the sun's

attractive force. Now, by the general law of gravitation, that attraction is always reciprocal, and it is certain that the comets attract the planets as strongly as the planets attract them, and if the masses of the comets were as great as those of the planets, they would cause the planets to deviate from their accustomed path as widely as the planets cause them to deviate. If, however, we find, that while the deviation of the comets, in virtue of this mutual attraction, is very great, that of the planets is extremely small, the inference must be that the masses of the comets are smaller than those of the planets, in exactly the proportion in which the effect of the attraction on the planet is less than its effect upon the comet.

Now, in fact, it has been found that while the deviation of the comets, due to the attractions of the planets, is very considerable, that of the planets, of the satellites, and even of the planetoids (the smallest bodies of the solar system), is so minute as to be absolutely inappreciable by the most exact means of observation. A case is even recorded in which a comet passed almost in contact with the satellites of Jupiter, if, indeed, it did not pass among these small bodies, yet its attraction upon them was so feeble as to produce not the slightest observable effect upon their motions, although the comet itself, by the attraction of the planet, was so strongly affected that its orbit was completely changed.

By such observations and calculations it has then been established that, although the comets are masses of ponderable matter, the quantity of matter composing each of them is incalculably less than that of the smallest planet, primary or secondary, of the solar system.

These bodies are as remarkable for the vastness of their magnitude, and the strangeness, variety, and mutability of their forms as for the smallness of their masses.

Comets in general, and more especially those which are visible without a telescope, present the appearance of a roundish mass of illuminated vapour or nebulous matter, to which is often, though not always, attached a train more or less extensive, composed of matter having a like appearance. The former is called the HEAD, and the latter the TAIL of the comet.

The tail is more significantly called the *brush* by Chinese astronomers.

The illumination of the head is not generally uniform. Sometimes a bright central spot is seen in the nebulous matter which forms it. This is called the NUCLEUS.

The nucleus sometimes appears as a bright stellar point, and sometimes presents the appearance of a planetary disk seen through a *nebulous haze*. In general, however, on examining the object

with high optical power, these appearances are changed, and the object seems to be a mere mass of illuminated vapour from its borders to its centre.

The nebulous haze which always surrounds the nucleus is called the COMA.

These terms COMA and COMET are taken from the Greek word κομή (komé) hair, the nebulous matter composing the coma and tail being supposed to resemble hair, and the object being therefore called κομήτης (kometes), a hairy star.

A telescopic view of one of the globular comets without a tail is given at the head of this chapter. This is the comet known as Encke's comet, so called from the astronomer who calculated its orbit.

This may be taken as a general representation of the apparent form of the comets without tails. The real form is evidently globular or spheroidal.

The comets with tails are infinitely various in form. In fig. 2 is represented the comet known as Halley's Comet, as it appeared on the 3rd October, 1835; and this may also be taken as a very general representation of comets with tails.

Fig. 2.

The rapidly changing and capricious forms of these singular bodies may be conceived from fig. 3, p. 70, which represents the same comet as it appeared on the 9th October; and the figure at the head of Chapter II. as it appeared on the 5th November.

Nothing which attends these extraordinary objects is more astonishing than their prodigious dimensions. The head of the great comet which appeared in 1811 was a globular mass, whose diameter

measured 1,250000 miles. Its bulk must, therefore, have been thrice that of the sun, and *nearly four million times that of the earth!* But astounding as this is, the dimensions of the tail were still more so. The length of that vast appendage was an hundred and thirty millions of miles, so that if the head were at the sun, the tail would extend to thirty millions of miles beyond the earth!

Supposing this tail to consist of continuous matter, let us see what its quantity must be by measure. Its diameter at the point where it emanated from the head was equal to that of the head, but as its sides were slightly divergent, its diameter increased as the distance from the head increased; but let us take it as equal only to the diameter of the head.

The length of the tail having been an hundred and thirty millions of miles, while the diameter of the head was a million and a quarter of miles, it will follow that the length of the tail was 104

Fig. 3.

times the diameter of the head. If the sides of the tail, instead of being divergent, were parallel, it would thence follow, by the principles of geometry, that the volume or cubical bulk of the tail must have been an hundred and fifty times greater than that of the head, and since the bulk of the head was four million times that of the earth, that of the tail and head together (without taking into account the effect of the divergence of the tail), must have been *nearly six hundred million times the bulk of the earth!!*

It must be observed, however, that some appearances observed in the tails of comets have suggested to astronomers the probability

that they may be hollow, that is to say, that instead of being cylindrical or conical columns of vaporous matter, they are thin cylindrical or conical *tubes* of vapour, like the funnel or pipe of a stove. In that case, of course, the bulk or volume of vaporous matter entering into their composition would be much less than we have here computed, but the actual volume included within their limits would still be the same.

In form the tails are sometimes straight, and sometimes curved like a scymeter, as represented in fig. 2. When the great comet of 1456 appeared it had that form; and in the superstitious spirit of that age, it was regarded as a celestial sign of the success of the Turkish invasion of Europe, from its resemblance to a Turkish sabre.

The tail is not always single. Comets have appeared with two or more tails. In 1744 a comet appeared with six tails, each of which was curved nearly to the form of a quadrant.

The magnitude of these enormous appendages is even less amazing than the brief period in which they are sometimes thrown out from the head. The great comet of 1843 had a tail which measured two hundred millions of miles, so that if the head were at the sun, the tail would extend to an hundred millions of miles beyond the earth. Yet this tail was thrown out in less than twenty days. If, as we must suppose, it was wholly composed of matter issuing from the head, with what inconceivable force must not the matter have been ejected which formed the extremity of the tail! The matter having been driven through two hundred millions of miles in twenty days, must have had a velocity of ten millions of miles per day. This would be at the rate of above four hundred thousand miles per hour, seven thousand miles per minute, or an hundred and fifteen miles per second.

This velocity is nearly six times that of the earth in its orbit, and is two hundred and fifty times greater than that of a cannon ball.

It may be easily imagined that the matter to which such a velocity could be imparted by the reaction of such a body as the comet (itself, according to all probability, consisting of mere vapour), must be infinitely attenuated.

But there are other proofs how light and rarified must be the matter composing these bodies.

Since the masses of comets are so infinitely minute, while their volumes are so prodigious, it must follow that the density of the matter composing them is exceedingly small, so small indeed, that they must be, bulk for bulk, immeasurably lighter than air or the most expansive vapour. Other appearances attending them are also consistent with this. Thus it has been found that

the smallest stars—stars so minute as to be barely visible by the aid of powerful telescopes, have been distinctly seen, and seen without any perceptible diminution of their lustre, through the very centre of the head of these bodies. It would follow, therefore, that the matter composing them is so attenuated that a thickness of so many thousand miles of it has no sensible imperfection of transparency.

There is, therefore, the strongest reason to conclude that the material of which comets are composed is vaporous or aëriform, and that it is in the most attenuated state that can well be imagined, being probably some thousand times less dense than our atmosphere.

It has also been ascertained on satisfactory grounds that this matter is not luminous, but, like the clouds which float in our atmosphere, is illuminated by the sun, and thus rendered visible. Some circumstances attending the variation of the magnitude of the visible material of these bodies also render it probable that they are composed of vapour, which when raised to a certain temperature by their proximity to the sun, becomes absolutely transparent and invisible, and which as the comet recedes from the centre of light and heat is gradually condensed and becomes visible, just as steam issuing from the safety-valve of a boiler is, at the moment of its escape and before its condensation, transparent and invisible, and assumes a greater and greater volume of whitish cloudy matter, as its distance from the valve and its exposure to the condensing effect of the cold air increases. In this way is explained the fact, that comets in general are augmented in their visible volume as they recede from the sun.

Such then being generally the nature and character of these bodies, so far as observation has enabled astronomers to determine them, it remains to inquire how far there are any grounds for the various effects and influences which have been ascribed to them.

4. Of all the effects which have been ascribed to comets, that of a collision with the earth is perhaps the least unreasonable.

That such an event is *possible*, cannot be denied. It remains, therefore, only to estimate its probability, and the effects it might produce if it occurred.

That a comet should encounter a planet, two conditions must evidently be fulfilled:—1st, the path of the comet must intersect that of the planet; and, 2nd, the two bodies must arrive at the same time at this point of intersection.

Now, of all the known comets there is not one of which the orbit intersects the orbit of any planet. There is, however, one *whose* orbit passes so near the earth's orbit, that the distance

between the two points where they are nearest is less than the semi-diameter of the comet, and it follows, consequently, that if the earth and comet were to arrive together at these points, the earth must pass through the comet. If the comet were solid, which it is not, a collision must take place. But being composed of the lightest and most attenuated vaporous matter, the effect would be the same as if the earth were to pass through a very thin cloud.

This particular comet happens to be one of the few which have been ascertained to revolve round the sun in a definite period like the planets, with this difference, however, that the orbit is a somewhat elongated oval instead of one which is nearly circular. The period of this comet being about six years and three quarters, it follows that it must pass through the place of danger to the earth once in that interval.

It passed through that place in 1832, under circumstances which excited among the world in general, who were taught to expect its approach, and to know its proximity to the earth's path, a certain panic of apprehension as to the possible consequences. These fears were however groundless, for the comet passed through the point of danger on the 29th October, and the earth did not arrive at that point until the 30th November. Now, since the earth moves at the rate of above a million and a half of miles per day, it follows that on the 29th October, the day on which the comet passed through the point of danger, the earth must have been nearly fifty millions of miles from that point.

In 1805, the same comet passed through the same point, under circumstances which, had they been as generally known as in 1832, might have more reasonably excited apprehension, for in that case the distance of the earth from the comet was only five millions of miles.

It may, nevertheless, be observed with truth, that although the danger of an encounter with the comets whose orbits are known, be insignificant, the risk with relation to the far more numerous class of these bodies, whose motions are unascertained and which pass continually among the planets may be much greater.

Nothing, however, is more easy than to apply to this question the well understood principles of the theory of probabilities, assuming such conditions respecting the number and magnitude of the comets, as all must admit to be the most favourable imaginable to the catastrophe of collision. This has been accordingly done. It has been shown that, assuming the number of comets which pass within the earth's orbit to be the greatest that it can be imagined to be, and that the magnitudes of these comets be

also the greatest that they can be conceived to be, the chances against a collision of the earth with any individual comet would be 281 millions to one.

Let us illustrate the meaning of this arithmetical conclusion. If a comet appear next month, and if such a comet, encountering the earth, would destroy the whole human race by the shock, how is the danger of such a catastrophe, as it affects each individual, to be estimated? We answer that this danger would be exactly the same as if 281 millions of white balls and one black ball were put into an urn, and that the death of the individual was to be the consequence of the single black ball being drawn from the urn by the hand of a blind man.

This conclusion, which is based upon strict mathematical reasoning, will, we presume, be sufficient to reassure the most timid and sensitive as to the danger of the collision of the earth with a comet.

5. Popular opinion is universal and emphatical in all countries that comets influence the temperature of the seasons, and although popular opinion is not always infallible, it is not to be lightly rejected.

All the world knows that the excellence of the celebrated vintage of 1811 was by common consent ascribed to the influence of the splendid comet which appeared in that year. The "wine of the comet" was long known, and bore a high price in the market. The abundant harvest of the same year was ascribed unanimously to the same cause.

An article appeared in the "Gentleman's Magazine," in 1818, upon the supposed influences of the comet of 1811, in which it was affirmed that, although the winter was mild, the spring humid, and the summer cold, the sun scarcely appearing with force sufficient to ripen the fruits of the earth, yet such was the effect of the comet that the grain harvest was exceptionally abundant, and certain sorts of fruits, such as melons and figs, were not only produced in unusual quantity, but had a delicious flavour. It was further observed wasps were few; that flies became blind, and disappeared early, and that the frequency with which women produced twins was especially remarkable! It even happened that the wife of a shoemaker at Whitechapel had four children at a birth!! and all these marvellous effects were ascribed to the comet.

As to the question of the influence of comets on the temperature of the seasons, it is one of the most simple and most easy of solution. In all observatories, the appearances and motions of the comets are recorded. The average daily and monthly and yearly temperatures of the weather are also exactly observed and

recorded. To ascertain, then, whether the comets really exercise any influence on the temperature of the seasons, it is only necessary to place in juxta-position the comets and the temperatures, and to examine whether there be any correspondence between them.

This was accordingly done by M. Arago. The records of the public observatories supplied the data necessary to make the comparison during the century which ended with 1832, and the result was that no correspondence whatever was discoverable. Sometimes it happened that the years of greatest mean temperature were those in which several comets appeared; in some they were those in which none appeared. In some cases the years signalised by the most remarkable comets were characterised by a high, in some by a low mean temperature. Thus in 1737, when two comets appeared, the temperature was lower than in the two preceding years when none appeared. Of the twenty years which commenced in 1763, the coldest, 1766, was that in which two comets, one of which was remarkable for its splendour, appeared. In an interval of 16 years, the warmest was 1794, in which no comet appeared, and the coldest was 1799, in which two were seen.

But omitting further notice of the thermal character of particular seasons, let us see what was the general result of this investigation. Of 74 years, 49 were signalised by the appearance of one or several comets, and 25 by their non-appearance. The mean temperature of the former years was found to be 51.°6, and that of the latter 50.°7, the difference being less than one degree.

Again, of the 49 years in which comets appeared, a single comet was seen in 25, and two or more comets in 24. If these bodies produced any influence on the temperature, a difference ought to be expected between the mean temperature of the latter and the former years. It was found, however, that the mean temperature of 25 years of a single comet was 51.°6, while that of the 24 years of several comets was 51.°4, the difference being only the fifth of a degree, and even that being *against* the influence of the comets in augmenting the temperature.

In fine, the complete discussion of the cometary and thermal observations, continued through an entire century, fully establishes the conclusion that there exists no foundation whatever for the popular opinion that the comets influence the seasons.

6. Of all the eventualities which may arise out of the motion of comets through the system, the least improbable and moreover that of which the consequences are most difficult to foresee, is the passage of the earth through the tail of one of these bodies.

The comets are exceedingly numerous; but few of them have

tails. These appendages where they exist are generally of very limited length, but in some rare instances, as has been already stated, their length is prodigious, extending over a space not less than the thirtieth part of the extreme diameter of the solar system. If such a comet had its head at the surface of the sun and its tail in the plane of the ecliptic, the tail would sweep over the space through which the planets, Mercury, Venus, the Earth and Mars move, and it might in that case encounter any or all of these planets.

It cannot, therefore, be denied that the immersion of the earth in the tail of a comet is a possible event. That it is extremely improbable, however, may be shown by the same reasoning as has been already stated in reference to the question of the probability of the collision of a comet and the earth, combined with the consideration that very few comets have tails of considerable length.

But, supposing such an event to take place, what would be the probable consequences?

It is certain that the matter composing the tails of comets is of such a nature that although these appendages have often a thickness measuring many thousand miles, the smallest telescopic stars are visible through it, without the least perceptible diminution of their lustre.

The matter of the tail being, therefore, so completely transparent, and producing moreover no perceptible refraction, its density, if it be vaporous or aëriform, must be extremely inconsiderable, and according to all probability, many thousands of times less than the density of our atmosphere.

If such be its nature, when the earth would pass through it, it would mingle with the terrestrial atmosphere, and if its density were, for example, a thousand times less dense than the air, the atmosphere would contain one particle of cometic matter to every thousand particles of pure air.

Let us suppose that the room we inhabit contains 10,000 cubic feet of air, and let 10 cubit feet of any noxious gas be introduced into it and mixed with the air. We should then take into the lungs in respiration one particle of the noxious gas with every thousand particles of pure air. So far as the possible injurious effects depend on the numerical proportion of impurity, there would appear in such case to be but little ground of reasonable fear.

We have, however, numberless examples of the strong effect produced upon our organs by effluvia with which the air is occasionally impregnated, which, nevertheless, prevail in a proportion *so minute* as utterly to escape the nicest and most exact analysis.

A grain of musk, or a single drop of the otto of roses, will be sensible to the organ of smelling in a large room, and will continue to be sensible for a long period of time. The actual proportion, nevertheless, which the material effluvia producing this powerful effect upon the organs bears to the total quantity of air impregnated with it is quite inappreciable.

It is pretended by some medical practitioners that the effluvia inspired in smelling certain medicaments is capable of producing on patients the effects of an aperient, and it is well known that the effects of an emetic are often produced by certain odours.

Such analogies, therefore, show that the extreme state of attenuation, which probably characterises the tails of comets, does not necessarily exclude the possibility of their producing formidable effects upon the organised world, if they should be mingled with the atmosphere.

7. This supposition has accordingly been adopted by some authors, and among them not a few holding a position of authority in the world of science, as the means of explaining the prevalence, at various epochs, of epidemic diseases.

Gregory, in a work on Astronomy, published at Oxford in 1702, affirmed that, among all people and in all ages, the appearance of comets has been attended with such general effects; and he adds that it does not become philosophers to treat such traditions with levity, or to reject them, without consideration, as mere fictions.

So recently as 1829, Mr. T. Forster, an English medical practitioner, published a work, entitled "Illustrations of the Atmospherical Origin of Epidemic Diseases," in which he professed to prove that, since the Christian era, the periods which have been the most insalubrious have been invariably those at which some great comet was visible. He maintains that the malignant influence of these bodies is not limited to the human race, nor even to the organised world. He ascribes to them innumerable effects upon the inferior animals, and all the violent changes incidental to the atmosphere besides earthquakes, volcanic eruptions, floods, droughts, and famines.

Comets appear on the average at the rate of very nearly two per annum. Now, it is generally assumed by the partisans of their influence that they exercise these effects for some time before their appearance, and for some time after their disappearance. It cannot, therefore, be surprising that those who favour this theory should find a comet for every epidemic or other visitation, whether physical, or physiological, which they desire to ascribe to such a cause.

Nevertheless, frequent as are the appearances of these objects,

and various as are the effects which the partisans of this theory are disposed to ascribe to them, cases have been presented in which the most ardent supporters of such a hypothesis are hard driven to find a misfortune or a malady to visit even upon the most formidable of the comets, and on the other hand, it is sometimes difficult to find a comet on which to saddle some of the greatest scourges which have visited our race.

One of the largest and most remarkable comets of modern times was that of 1680. It was also that which passed nearest to the sun, and not very far from the earth. Nevertheless the partisans of cometary influences have found it difficult to discover any calamity to visit upon that body. There were no epidemic diseases, local or general, to ascribe to it; but Mr. Forster assigns it as the cause of a cold winter, followed by a dry and warm summer, and some remarkable meteors seen in Germany!

The year of the great plague of London (1665) was signalised by a comet which appeared in the month of April, and to the influence of which that visitation was, of course, ascribed. No reasons, however, are given why London alone was obnoxious to this malign influence, and why no similar effect was produced in other European capitals, or even in other great towns of England, nor even in many of the villages with which London is begirt.

To this and all similar speculations it may be answered that, admitting the possible influence of comets, their effect ought to be general and not local. There can be no imaginable reason why such a body should affect, in a special manner, one particular spot upon the earth's surface, while the surrounding countries are exempt from the like consequences of its influence.

This is the conclusive answer to all the absurd speculations on cometary influences which fill the elaborate treatises of Gregory, Sydenham, Lubienetski, Forster, and others. Some of these effects appear so ludicrous that it is difficult to quote them in any serious discussion on a question of physical science.

A great comet appeared in the heavens in 1668, which there is some reason to suppose to be identical with the splendid object which passed through the system in 1843. One of the advocates of cometic influences discovered that the presence of this body in 1668 produced a remarkable epidemic among *cats in Westphalia!* We have not heard of any similar calamity in 1843.

8. A comet, not very conspicuous either for magnitude or brightness, passed near the earth in 1746. The destruction of the cities of Lima and Callao by an earthquake is imputed to this body, but no reason is assigned for the exemption of other cities of the South American continent.

9. To another comet is ascribed the destruction of a steeple-

clock in Scotland, by the fall of a meteoric stone; to another, the prevalence of flocks of wild pigeons in America; to another, remarkable eruptions of Etna and Vesuvius. The authors who, at great labour of research, rake together such incidents, make a vain display of erudition, and, as M. Arago wittily observed, are under a delusion similar to that of a lady mentioned by Bayle, who never looked out of the window of her apartment, situated in the greatest thoroughfare of Paris, and saw the street filled with carriages, without imagining that her appearance at the window was the cause of the crowd.

The celebrated traveller, Rüppel, writing from Cairo, on the 8th of October, 1825 (in which year three comets appeared), observed that "the Egyptians thought the comet then visible was the cause of the shocks of an earthquake which were felt in that country on the 21st of August, and that the same object exercised so malignant an influence on some of the lower animals, that horses and asses perished in great numbers. The truth was, that the poor animals died of starvation, the deficiency of the overflowings of the Nile having produced a scarcity of their forage."

"If I were not restrained by considerations of politeness," observed M. Arago, "I should find no difficulty in proving that, as far as respects astronomical information, there are other Egyptians beside those which are found on the banks of the Nile."

Physical effects are not the only influences imputed to comets. The comet now so familiarly known to the public as that of Halley, and whose last periodical re-appearance took place in 1835, appeared with extraordinary splendour in 1305, being described as "Cometa horrendœ magnitudinis visus est circà ferias paschatis, quem secuta est pestilentia maxima." Thus, as usual, the great plague was laid to the account of this body.

The next visit but one which the same comet paid to the solar system was in 1456, when it is represented as having an "unheard-of magnitude," and as having a tail which extended over sixty degrees of the heavens, being two-thirds of the distance from the zenith to the horizon. It was visible thus during the month of June, and spread terror throughout Europe. It was regarded as presaging the rapid success of the Turks under Mohammed II., who had taken Constantinople, advanced to the walls of Vienna, and struck terror into the whole Christian world. Pope Calixtus II., terrified for the fate of Christianity, directed the thunders of the Church against the enemies of the faith terrestrial and celestial, and in the same bull exorcised the Turks and the comet; and in order to perpetuate this manifestation of the power of the Church, he ordained that the bells should be rung at noon, a custom still observed in Catholic countries. Neither the progress of the

comet, nor the victorious arms of the Mohammedans, were, however, arrested. The comet tranquilly proceeded in its orbit, passing through its appointed changes, regardless of the thunders of the Vatican, and the Turks established their principal mosque in the Church of St. Sophia.

A comet appeared in the year 590, to the presence and influence of which was ascribed a fearful epidemic, which prevailed in that year, in the crisis of which the patients were seized with violent paroxysms of sneezing, often followed by death. It became the custom, therefore, when these paroxysms manifested themselves, for the bystanders to address their benediction to the sufferer, exclaiming, "God bless you." This custom became permanent and universal, and to this day the sneezer is addressed in the same words

TELESCOPIC VIEW OF HALLEY'S COMET ON 5TH NOVEMBER, 1835, BY STRUVE.

COMETARY INFLUENCES.

CHAPTER II.

10. The birth and death of heroes, &c.—11. Questions discussed as to whether the dry fog of 1783 or that of 1831 was produced by the immersion of the Earth in the tail of a Comet.—12. Influences of atmospheric disturbances and currents in producing extraordinary effects on epidemic diseases—The periodical wind called Harmattan from the interior of Africa.—13. Question discussed as to whether the Earth at any former epoch has been struck by the solid nucleus of a Comet—Its consequences.—14. Questions discussed as to whether the geographical condition of the Earth has ever been disturbed by the near approach of a Comet, and whether the Biblical Deluge can have been produced by such a cause.—15. Probability of the terrestrial equilibrium being injuriously deranged by near approach of a Comet reduced to nothing.—16. Opinions of Laplace.—17. Curious phenomena of Biela's comet.

10. As we go further back in history, the moral and political influences imputed to comets are multiplied in proportion to the darkness of these times. These objects have been supposed more especially to have portended the birth and the death of heroes. Thus a comet which appeared in 43 B.C., and which was stated to be so brilliant as to be visible to the naked eye in the day time,

was regarded by the Romans as the soul of Julius Cæsar (who was then recently murdered), transferred to the heavens.

A comet which appeared at the epoch of the birth of Mithridates, and another which was seen immediately before the birth of Mohammed, were each regarded as the portents of these historical celebrities.

A comet, supposed to have signalised the birth of Christ, was said to have appeared during an interval of twenty-four days, producing a light *surpassing that of the sun* (!), and with a magnitude which extended over a fourth part of the firmament, so as to occupy four hours in rising and setting.

The exaggeration of such statements must become glaringly apparent when it is considered that comets like planets and the moon derive all their light from the sun.

A comet appeared in March, 1402, the splendour of which is stated to have been so great, that it was visible at noon. A second appeared in the same year in June, which was so brilliant as to be visible for some hours before sunset. This comet was said to presage the death of John Galéas Visconti. That prince, being a believer in astrology, had consulted the charlatans of the day, and the fright produced by the appearance of the comet no doubt contributed to the fulfilment of the prediction.

Another conspicuous comet appeared in 1532, which was also stated to be visible before sunset. It produced much excitement in Northern Italy, where it was considered to presage the death of Sforza II.

11. It has been conjectured, not without some show of probability, that the great dry fogs which spread over a large portion of the surface of the earth in 1783 and 1831, were produced by the passage of the tail of a comet over the earth or over a part of it.

The great fog of 1783 had several characters which would entitle it to serious consideration in relation to this question. It commenced nearly on the same day (the 18th of June), at places very distant from each other, such as Paris, Avignon, Turin, and Padua. It covered a part of the earth's surface, extending north and south from Africa to Sweden. It prevailed on the North American as well as upon the European continent. It can scarcely, therefore, be denominated a local phenomenon in the ordinary use of that term.

It lasted for a month. That the atmosphere did not convey it over the regions in which it prevailed was proved by the fact that its position was not affected by the winds. Whatever direction the wind took, the position of the fog remained the same. It prevailed equally at all accessible heights above the surface. It was as dense upon the summits of the Alps as upon the plains of France.

The heavy and constant rains which fell in June and July, and the storms of wind which accompanied them, did not dissipate it.

Its density and partial opacity varied in different places. In Languedoc it was so dense, that the sun was not visible at altitudes below 12°; and at greater altitudes its light was red, and so subdued, that it could be looked at without inconvenience.

The quality by which it was distinguished from common fogs was its absolute dryness. Hygrometric instruments exposed in it indicated the complete absence of humidity.

One of the most remarkable circumstances, however, attending it was, that it appeared to be endowed with some faintly luminous quality, such as might be supposed to proceed from a slight degree of phosphorescence. Thus it appeared from the declarations of many observers that, while it prevailed at the epoch of new moon, and therefore in the total absence of moonlight, the light proceeding apparently from the fog was sufficient to render objects visible at distances of two or three hundred yards.

Such being the actual phenomena, it remains to be considered whether the hypothesis that the earth passed at that time through the tail of a comet can be admitted to explain them.

In the first place, it must be observed that the *head* of the comet, if such a body were present, was not visible. This cannot be explained by the supposition that the tail rendered the head invisible, inasmuch as the fog did not prevent the stars being seen as usual at night in all places where it prevailed.

It has been suggested that the position of the head might have been such, that it rose and set with the sun, or nearly so, and could not therefore be seen in the absence of that luminary either before sunrise or after sunset. But although this might be admitted for a very short interval, its continuance for a month would not be compatible with what is known of the motion of comets. If it were a comet, the tail being generally turned from the sun, the head must have been within the earth's orbit, and between the earth and sun, or nearly so. The angular motion of the comet must have been such as to remove it from the position of inferior conjunction in the course of a few days, after and before which the head would have either risen before the sun, or set after it, and so would have been visible. No such object, however, was seen at or near the time of the great fog of 1783.

No combination of any possible orbital motion of the comet with the orbital and diurnal motion of the earth has been or can be suggested which would be compatible with the position and continuance of the great dry fog of 1783. It may therefore be concluded

that that phenomenon did not arise from the immersion of the earth in the tail of an unseen comet.

The great fog of 1831 is subject to nearly the same observations, and the cometary hypothesis is removed by nearly the same reasoning. This fog was manifested during the month of August. It spread over the three continents of the northern hemisphere, commencing on the north coast of Africa on the 3rd, at Odessa on the 9th, throughout France on the 10th, in the United States on the 15th, and in China during the latter part of the month.

The sun's light was so enfeebled, that it could be looked at without coloured or smoked glass. On the coast of Africa, the sun was not visible at all at altitudes below 15° or 20°; yet the nights were so clear, that the stars were visible. Observers in the north of Africa, in the south of France, in the United States, and in China, reported that the disk of the sun seen through the fog had the tint of azure, and in some places of emerald green.

This appearance was explained by the supposition of the well-known optical illusion called "accidental colours." The fog or the clouds around the solar disk, and through which the latter was seen, being, like fogs and clouds in general, when seen by the transmitted light of the sun, reddish, the white disk of the sun seen in juxta-position with them would, by the mere effect of contrast, appear to be bluish or greenish, according to the tint of red transmitted by the surrounding clouds.*

Like the great fog of 1783, this fog seemed to have a proper light. During its prevalence there was, strictly speaking, no nocturnal darkness. During the month of its prevalence there was light enough at midnight to read the smallest written or printed characters. This fact was reported equally by observers in places the most distant, as in Italy, Prussia, Siberia, &c.

Since twilight ceases when the depression of the sun below the horizon exceeds 18°, and since at these places, in August, the depression considerably exceeds that limit, it is evident that the light thus observed could not have been common twilight.

Whatever may be the explanation of this phenomenon, that of the immersion of the earth in the tail of a comet is overthrown completely by the fact that the fog, though extensively spread, was not continuous, much less uniform. Some parts of the European continent were altogether or nearly free from it, and in other parts it was developed in very different degrees. The times of its continuance in different places also varied much and

* *See Lardner's* "Hand-Book of Natural Philosophy" (1159).

irregularly, and in such a manner as to be quite incompatible with the cometary hypothesis.

The cometary hypothesis, then, being rejected, it has been suggested that these fogs may have had much nearer and less extraordinary causes. It was recorded that great physical commotions were manifested at opposite extremities of Europe in the year 1783. In the month of February terrible and long-continued shocks of an earthquake took place in Calabria, which produced great devastation, and by which more than 40,000 inhabitants of that country were buried under the ruins of overturned houses and buildings, and in the profound crevices of the cracked crust of the earth. At a later part of the year, Mount Hecla underwent the most violent eruptions ever witnessed, and new craters were opened at various points at the bottom of the surrounding sea, and even at considerable distances from the shore.

Considering these and like commotions, it has been suggested that the vapour, smoke, and gaseous matter ejected in enormous quantities during such eruptions, dissipated by the winds, might have been diffused through the atmosphere over the countries where the fog prevailed.

Another supposition assigns these fogs to the same cause as that which produces showers of meteoric stones, noticed in another number of this series. Among the various forms assumed by this class of bodies, that of showers of fine dust is not unusual. Now, we have only to admit the possibility of a still greater degree of attenuation, to reduce such dust to the condition of the matter composing a dry fog. This explanation would be quite compatible with the local and unequal distribution of the phenomenon.

Several medical authorities conjectured that the fog of 1831 might have been the cause of the epidemic cholera which prevailed about that time. This supposition, however, is overturned by the fact of the frequent prevalence of the same epidemic since then, at epochs at which no such fogs were seen.

12. Nevertheless, facts are recorded which render it certain the atmospheric disturbances and currents do produce extraordinary and hitherto unexplained effects upon epidemic diseases. A very curious and remarkable instance of this influence is quoted by M. Arago from the narrative of Matthew Dobson, an English traveller.

"A periodical wind, called Harmattan, blows three or four times a-year from the interior of the African continent towards the Atlantic coast, between latitudes 15° north, and 1° south. The periods of its prevalence are stated to be chiefly from the end of November to the beginning of April, its direction varying from east-south-east to north-north-east. Its duration at any one time

varies from one to six days, and its force is always very moderate. A fog, thick enough to render the disk of the sun red, always accompanies this wind. The particles deposited by this fog upon the leaves of vegetables and on the black skin of the natives appears always white, but the nature of this whitish matter was not ascertained. It was remarked that this fog was speedily dissipated by the sea; for although the wind was sensible on sea at many leagues from the coast, the fog became rapidly less dense, and, at the distance of little more than a league, it disappeared.

"One of the characteristics of this wind and fog is extreme dryness. When it continued for any time, the foliage of the orange and lemon trees exposed to it became shrivelled and withered. So extreme is this dryness, that the covers of books, even when closed, locked in chests, and enveloped in linen cloth, were curved by it just as if they had been exposed to the heat of a strong fire. The panels of doors and frames of windows, and the furniture, were often cracked and broken by it. Its effects upon the human body were not less marked. The eyes, lips, and palate were parched and painful. If the wind continued unabated so long as four or five days, the face and hands grew pallid. The natives endeavoured to counteract these effects by smearing their skin with grease."

Considering all these effects, it might be naturally inferred that the Harmattan must be highly insalubrious; yet observation proved it to have the extreme opposite quality. It was found that its first breath completely banished intermittent fevers. Those who had been enfeebled by the practice of excessive bleeding, then prevalent there, soon recovered their strength. Epidemic and remittent fevers, which had a local prevalence, disappeared as if by enchantment. But the most wonderful effect of this atmospheric phenomenon was, that it rendered infection incommunicable, even when applied by artificial means, such as inoculation.

There was at Wydah, in 1770, a British slave ship called the *Unity*, having on board a cargo of above 300 negroes. The small-pox having broken out among them, the owner resolved on inoculating those who had not taken the natural disease. All those who were inoculated before the commencement of the Harmattan took the disease, but of seventy that were inoculated on the second day after its commencement, not one took the infection; yet after the lapse of some weeks, when the Harmattan ceased these seventy negroes took the natural disease. Soon after they were attacked by it, the Harmattan recommenced, and the disease almost immediately disappeared.

The country over which the Harmattan blows, for more than a hundred leagues, is a series of extensive plains covered with verdure, with a few patches of wood here and there, and intersected by a few rivers, with some small lakes.

13. Various phenomena have raised the question whether at any remote epoch of its physical history the earth was ever struck by the solid nucleus of a comet.

We have already stated the circumstances which render it highly probable that the comets generally are mere masses of aëriform or vaporous matter. Nevertheless, although this be certain as respects the large majority of these bodies, some among them, more especially those which appeared at remote dates, have had a splendour which it would be difficult to imagine to be produced by the reflection of the sun's light by mere vaporous matter; and even in modern times, since the instruments of observation have been improved, and observers have increased in zeal, activity, and vigilance, and have been greatly multiplied in number, appearances of a nucleus have been observed which some astronomers have considered to afford pretty conclusive evidence of the existence of a solid nucleus within the nebulous envelope; and although many entertain doubts of this, it cannot be said that the existence of a solid nucleus in some of the many comets which have passed through the system is absolutely disproved.

Assuming, then, the possible existence of a solid comet, and considering the possible (however improbable) eventuality of such a body and the earth passing at the same moment through the same point of space, it may be reasonably asked,

What would be the consequences of such a catastrophe?

It must be observed, in the first place, that admitting the bare possibility of certain comets having a solid nucleus, such a mass must be less, incomparably, than the smallest body of the solar system. The grounds upon which this inference rests, have been already stated.

Now, assuming the earth to move round the sun, and at the same time to have a diurnal rotation upon a certain diameter as its axis, let us see what would happen if it were to receive suddenly a blow, from a much smaller solid mass encountering it.

If, in case of such an event, the earth had no previous motion of rotation, and if, as would probably happen, the direction of the blow given to it did not pass through its centre, it would receive a motion of rotation round an axis at right angles to the plane drawn through the direction of the blow and the centre of the earth, and the time of rotation would depend on the distance of the centre of the earth from the direction of the blow.

If, however, the earth, before receiving the blow, had already a

motion of rotation, the effect of the blow would be to change either its axis of rotation or the time of rotation, or both one and the other. Its new axis of rotation would have a certain position between its previous axis and that upon which the blow would have made it revolve if it had no previous rotation. The determination of this new axis would be a problem of no difficulty.

Such being the immediate consequences of such a collision, it remains to consider what would be its secondary results.

If a carriage moving uniformly on the smooth surface of a railway, or a boat propelled or drawn uniformly on the surface of water, receive an impulse by which its speed is suddenly changed, all loose bodies upon it will be thrown backward or forward, according as its speed is increased or diminished, inasmuch as they do not at first participate in the increase or diminution of velocity imparted to the vehicle on which they are placed. Hence it happens, that if a horse going at speed suddenly retards his motion, or stops, the rider is thrown forward, and if he suddenly starts forward with increased speed, the rider is thrown backwards.

A similar disturbance of position would be produced by a change of direction of the motion of the vehicle. If it suddenly turn to the right, loose bodies will fall to the left, and *vice versâ*.

The earth, moving in its annual course round the sun, and at the same time revolving uniformly upon its axis, producing the vicissitudes of day and night and the succession of seasons, must be regarded as a vehicle upon which all loose bodies, such as air, water, and other fluids, animals, and all natural and artificial objects, not planted and firmly fixed in the solid ground, are transported, first round the axis of rotation by the diurnal motion, and secondly, round the sun by the annual motion of the earth in its orbit. Now if, under such circumstances, either of these motions were to receive a sudden change either in velocity or direction, the fluids composing the atmosphere, and the oceans, seas, lakes, and rivers, not partaking of that change, would, for the reasons explained above, be thrown from their position of relative equilibrium. Violent atmospheric commotions would ensue. The waters of the oceans and seas, thrown from their beds, would inundate the continents; rivers would change their directions, and either run in new channels or inundate the surrounding plains; lakes would desert their positions, and would flow in any channels open to them, or would flood the surrounding countries. Animals would be precipitated against all solid objects near them, with a force greater probably than that of a cannon-ball. Trees would be torn from their roots; buildings, especially such as have much elevation, would be overthrown; and if the *change of motion* were of a certain intensity, lofty mountain peaks

would be cast into the adjacent plains or valleys. It is evident that a general destruction of the organised world would be inevitable.

But even though the change of axis and the change of velocity of rotation of the earth might be so very inconsiderable, owing to the smallness of the mass of the striking comet and other causes, that such devastation might not take place, other effects would ensue which would speedily show the disturbance consequent on such a catastrophe. The least change in the axis would cause a corresponding change in the position of the terrestrial poles and the equator. The latitudes and longitudes of all places on the earth would suffer a change, the extent of which would be commensurate to the change of position of the axis of rotation.

But it is demonstrated in mechanics that a spheroid, such as the earth is known to be, cannot permanently revolve round any axis except its shortest diameter, that is the diameter which passes through the two points which form the centres of its flatness; and such we know by exact and numerous observations to be the axis upon which the earth actually revolves. Now, if by the collision of a solid comet the earth were made to revolve on any other diameter, it could not continue so to revolve. It would change its axis from hour to hour until at length it would again revolve round its shortest diameter.

But during this continual change of axis, what inconceivable physical and geographical confusion would arise! Not only would the latitudes and longitudes of places be constantly changed, but their climates and seasons, the conditions and qualities of their vegetable productions would undergo corresponding variations. Animals would migrate from country to country, seeking a congenial climate, and flying from vicissitudes and extremes of temperature which their instincts would not fail to tell them are incompatible with their well-being. The distribution of land and water, though perhaps exempt from the devastating effects attending extreme changes of velocity and direction, would nevertheless gradually undergo a total and general change, and the geographical features of the earth, the land-marks of nations and races, would be utterly deranged and effaced.

To answer the question, then, whether the earth has ever at any epoch been struck by the solid nucleus of a comet, we have only to examine whether there be any traditions in history, or any physical traces on the surface of the globe, of phenomena such as we have described above.

It is scarcely necessary to observe that, in the records of history and the traditions of nations, there are no traces of any such

catastrophe as that which we have here described. The deluge, which we shall presently notice, did not correspond to the conditions stated. That there are indications on the crust of the earth which prove that many parts of the continents, now elevated to considerable heights above the level of the sea, were at some former epoch submerged, is incontestable. The researches of geologists have established this fact. But the manner in which these marine deposits are found to be disposed is not such as a change in the earth's axis or in its time of rotation would explain. These deposits are frequently horizontal, of great breadth, very thick, and very regular. The varied and often very small shells found in them have preserved their most delicate points, their most brittle parts, unbroken. Every circumstance, then, dissipates the idea of a violent transposition; everything shows the deposits to have been formed on the spot. What now remains to complete the explanation without having recourse to an eruption of the sea? It must be admitted that the mountains and undulating grounds upon which they are based have risen up from below, like mushrooms; that they have grown up through the bosom of the waters. In 1694, Halley already cited this hypothesis as a *possible* explanation of the presence of marine productions upon the sides and on the summits of the highest mountains. This explanation is at present generally admitted. A comet which should perceptibly alter either the movement of rotation or the progress of translation of the earth would, without any doubt, occasion terrific convulsions in the shell of the globe; but, it must be repeated, these physical revolutions would differ in a thousand circumstances from those which are at present the objects of geological research.

14. *Has the geographical condition of the earth been ever disturbed by the near approach of a comet? Can the biblical deluge have been produced by such a cause?*

A remarkable comet appeared in the year 1680, which has been rendered memorable by the attempt of Whiston to prove that it was periodic, and that on one of its former visits it was the proximate cause of the Mosaic deluge. Arago, in his essays on comets, has discussed fully the question raised by Whiston.

Whiston proposed to show not only in what manner a comet might have occasioned the deluge of Noah, but was desirous, moreover, that his explanation should agree minutely with all the circumstances of that great catastrophe as related in Genesis. Let us see how he has succeeded in his object.

The biblical deluge happened in the year 2349 before the Christian era according to the modern Hebrew text; or the year *2926, after* the Samaritan text, the Septuagint, and Josephus. Is

there, then, reason to suppose that at either of those periods a great comet had appeared?

Among the comets observed by modern astronomers, that of 1680 may, from its brilliancy, without hesitation, be placed in the first rank.

A great many historians, both native and foreign, mention *a very large comet, in similitude to the blaze of the sun, having an immense train,* which appeared in the year 1106. In ascending still higher, we find a very large and terrific comet designated by the Byzantine writers by the name of Lampadias, because it resembled a burning lamp, the appearance of which may be fixed in the year 531. A comet appeared in the month of September, in the year of the death of Cæsar, during the games given by the Emperor Augustus to the Roman people. That comet was very brilliant, as it became visible from the eleventh hour of the day, that is, about five o'clock in the evening, or *before sunset.* Its date is in the year 43 before our era.

Let us, then, compare the dates of these appearances:—

From 1106 to 1680 we find	574 years.
,, 531 ,, 1106 ,, ...	575 ,,
,, 43 B.C. to 531 we find . . .	575 ,,

These periods may be regarded as equal to each other, and thence it appeared probable enough that the comets of the death of Cæsar, of 531, of 1106, and of 1680, have been only the reappearances of one and the same comet, which, after having run through its orbit—after having made its complete revolution in about five hundred and seventy-five years—became again visible from the earth. Then if the period of five hundred and seventy-five years is multiplied by four, we have twenty-three hundred, which, added to 43, the date of Cæsar's comet, gives, with the difference of only six years, the epoch of the deluge, resulting from the modern Hebrew text. In multiplying by five, the date of the Septuagint is found within eight years.

If we recollect the marked differences of the comet of 1759 in the period of its revolution round the sun, we shall acknowledge that Whiston might legitimately have felt authorised to suppose that the great comet of 1680, or of the death of Cæsar, was near the earth at the period of Noah's deluge, and that it had some part in that great phenomenon.

We shall not stop to explain minutely the series of transformations by which the earth, which, according to Whiston, was originally a comet, became the globe we now inhabit. It is enough to observe that he considered the nucleus of the earth as a hard and compact substance, which was the ancient nucleus of

the comet; that the matters of various natures confusedly mixed which composed the nebulosity, subsided more or less quickly, according to their specific gravities; that then the solid nucleus was at first surrounded by a dense and thick fluid; that the earthy matters precipitated themselves afterwards, and formed a covering over the dense fluid—a kind of crust, which may be compared to the shell of an egg; that the water, in its turn, came to cover this solid crust; that in a considerable degree it became filtered through the fissures, and spread itself over the thick fluid; that, in fine, the gaseous matters remaining suspended, purified themselves gradually, and constituted our atmosphere.

Thus, according to his theory, the great biblical abyss is supposed to consist of a solid nucleus and of two concentric orbs. Of these orbs, that nearest to the centre is formed of a heavy fluid which first precipitated itself; the second is of water; it is then, properly speaking, upon the last of these fluids that the exterior and solid crust of the earth reposes.

It is proper now to examine how, after the constitution of the globe to which at least many geologists could oppose more than one difficulty, Whiston explains the two principal events of the deluge described by Moses.

"In the six hundredth year of Noah's life," says the book of Genesis, "on the seventeenth day of the second month, the same day were *all the fountains of the great deep broken up, and the windows of heaven were opened.*"

At the period of the deluge, the comet of 1680, says Whiston, was only nine or ten thousand miles from the earth: it attracted, therefore, the water from the great deep, as the moon at present attracts the waters of the ocean. Its action, on account of that great proximity, must have tended to produce an immense tide. The terrestrial shell could not resist the impetuosity of the inundation; it broke in at a great number of points, and the waters, then free, spread themselves over the continents. The reader will here recognise *the rupture of the fountains of the great deep.*

The ordinary rains of our days, even continued for forty days, would have produced but a small accumulation. In taking for daily rain that which falls at Paris annually, the produce of six weeks, far from covering the highest mountains, would scarcely have formed a depth of eighty feet. It was therefore necessary to refer to other sources *than the cataracts of heaven.* Whiston has found them in the nebulosity and tail of the comet.

According to him, the nebulosity reached the earth near the Gordian (Ararat) mountains. Those mountains intercepted the *entire* tail. The terrestrial atmosphere, thus charged with an *immense quantity* of aqueous particles, was sufficient to produce

forty days' rain of such violence as the ordinary state of the globe can give us no idea.

Notwithstanding all its strangeness, we have stated the theory of Whiston in detail, both on account of the celebrity which it has so long enjoyed, as well as because of the consideration due to the man whom Newton himself designed as his successor in the University of Cambridge; yet the following are objections which it seems his theory cannot resist.

Whiston having required an immense tide to explain the mystery of the biblical phenomena of the great deep, was not content to pass his comet extremely near the earth at the moment of the deluge: he has, moreover, given it a very great magnitude, in supposing it six times greater than the moon.

Such a supposition is completely gratuitous, but this is its least fault; for it is not sufficient to account for the phenomena. If the moon produces a tide on the waters of the ocean, it is because its angular diurnal motion is not very considerable; that in the space of some hours its distance from the earth scarcely varies; during a considerable time it remains vertically over almost the same points of the globe; the fluid which it attracts has therefore always time to yield to its action before it moves to a region where the force which emanates from it will be otherwise directed. But it was not the same with the comet of 1680. Near to the earth, its apparent angular motion must have been extremely rapid; in a few minutes it corresponded with a numerous series of points situated on terrestrial meridians very distant from each other. As to its rectilinear distance from the earth, it might, without doubt, have been very small, but only during a few instants. The union of these circumstances, it must be observed, was but little favourable to the production of a great tide.

It is true that, to diminish these difficulties, it is sufficient to increase the comet—to make its mass not only six times the size of the moon, but thirty or forty times larger: but the comet of 1680 does not afford that latitude. On the 1st of November in that year it passed very near to the earth. It is shown that at the period of the deluge its distance was not less; then, as in 1680 it produced neither celestial cataracts, nor terrestrial tides, nor ruptures of the great deep; as, moreover, its train nor its nebulosity did not inundate us, we may in all confidence say that Whiston's theory is a mere romance, unless, in abandoning the comet of 1680, we venture to attribute the same effect to another much more considerable object of the same description.

In fine, we must observe that, even the argument of Whiston, based upon the apparent equality of the supposed successive appearances, from which he deduces a period of 574 or 575 years

other, one of which was directed to the place which had been occupied by the companion.

It is suspected that the faint comet which was observed at Rome by Prof. Secchi to precede Biela's comet in 1852, may have been the companion thus separated from it; and if so, the separation must be permanent, the distance between the parts being greater than that which separates the earth from the sun.

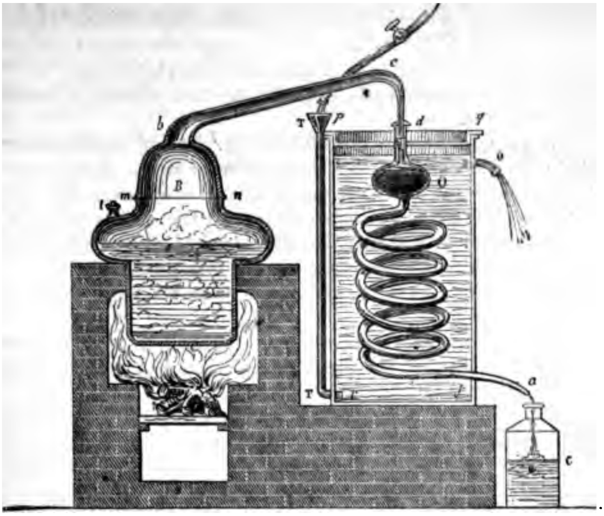


Fig. 1—DISTILLING APPARATUS.

COMMON THINGS.

WATER.

1. Water may be solid, liquid, or vapour.—2. Colourless and tasteless.—3. Its weight.—4. Expands by heat.—5. Point of greatest density.—6. Freezing-point.—7. Boiling.—8. Evaporation.—9. Heat absorbed in evaporation.—10. Superficial evaporation.—11. Saturation of air by vapour.—12. Process of drying.—13. Case of roads and paths.—14. Drying linen.—15. Wind promotes drying.—16. Water never naturally pure.—17. Contains fixed air.—18. And other substances in solution—Hard water.—19. Soft water.—20. Mineral springs.—21. Filtration.—22. Filtering-paper.—23. Artificial filters.—24. Water not absolutely colourless.—25. How to obtain water absolutely pure.—26. Rain water nearly so.—27. River water.—Thames water.—28. Water not an element—Its composition.—29. Methods of purifying it.—30. Distillation of water.—31. Conversion of vapour into water.—32. Weight of vapour.—33. Condensation.—34. Distilling apparatus.—35. Composition and decomposition.—36. Oxygen and hydrogen.—37. Hydrogen.—38. Fitted for balloons.—39. Inflammable.—40. Water produced by combining oxygen and hydrogen.—41. Apparatus for this experiment.—42. Composition of water.—43. Analysis of water.—44. By voltaic current.—45. By other methods.—46. By potassium and sodium.—47. By iron.

1. Next to air water is the most common of natural substances. It is less universally present, and although the uses to which it subserves are not less numerous and important, the want of it on the part of the animal and vegetable creation cannot be regarded as so incessant.

Water, according to certain varying physical conditions, may exist either in the solid, liquid, or vaporous state. It is perhaps in the last state that it is most universally diffused over the surface of the globe; but not being so obvious to the senses as it is when in the former two states, it is not recognised except by those who are familiar with the scientific tests of its presence.

It is therefore in the liquid form that we are most familiar with it.

2. At ordinary temperatures, and exposed to common atmospheric conditions, pure water is a colourless and tasteless liquid, having great transparency.

3. Its weight in relation to its bulk is very easily remembered, for it has been found that a cubic foot weighs almost exactly a thousand ounces, the temperature being 60°, the ordinary temperature of the atmosphere in these climates.

It may also be easily remembered that an imperial gallon of pure water, at this temperature, weighs 10 lb., and consequently that an imperial pint or the eighth part of a gallon weighs $1\frac{1}{4}$ lb.

4. All liquids expand or swell when heated, and contract when cooled. This is a general fact with which every one is familiar. Water is not an exception to this. A gallon of boiling water will be less than a gallon when it becomes cold, and a gallon of cold water will be more than a gallon when it is heated.

Water is therefore rendered more dense, that is to say, heavier in a given bulk, by cooling it, and less dense, that is lighter in a given bulk, by heating it.

5. There is, however, at a certain point in the thermal scale, a very striking exception to this general law in the case of water. If it be gradually cooled, its dimensions will continually contract, and it will become denser and denser until its temperature is reduced to $38°\frac{8}{10}$ of Fahrenheit's thermometer. But when it is cooled below that point, instead of contracting, it is found to expand; instead of becoming denser and heavier, it becomes less dense and lighter.

Water, therefore, bulk for bulk, is heavier and denser at the temperature of $38°\frac{8}{10}$ than at any other temperature, whether higher or lower.

This is therefore called the "temperature of greatest density."

6. When the temperature is reduced to 32° water becomes solid. *This change* from the liquid to the solid is called congelation

or freezing, and the temperature 32° at which it takes place, is called the freezing point of water.

7. If water be exposed to any source of heat, such as a fire or a lamp, it will, as may be naturally imagined, become continually hotter and hotter, but this increase of heat will not be unlimited. It will, on the contrary, after a certain continuance of the action of the fire or lamp upon it, attain a degree of heat or temperature which it will never exceed, however intense or long continued the action of the fire may be. In the ordinary state of the atmosphere, this temperature is that marked 212° on the thermometer. If a thermometer be immersed in the water, it will stand constantly at this temperature, although the action of the fire upon the water still continues.

When the water attains this stationary point of temperature it will be observed to be affected by a violent agitation throughout every part of it. Bubbles of vapour are formed at the parts of the vessel which are next the fire, and these rising with a certain violence, escape continually from the surface and produce the peculiar agitation of the liquid which has been just mentioned.

This state of water is called EBULLITION or BOILING, and the stationary temperature of 212°, at which it takes place, is called the BOILING POINT of the thermal scale.

8. Until the water exposed to the action of fire has attained the boiling-point, the heat imparted to it is employed in raising its temperature, or, in familiar language, in rendering it hotter. But after it has attained the limit of its temperature, and ceases to be rendered hotter, the fire still continues to impart the same heat to it, and it may be asked, What becomes of this heat? How is it absorbed, employed or disposed of? since it is certain that the water does not receive it.

This is easily explained. The water which the vessel contains does not become hotter, and therefore can receive none of the heat imparted by the fire, but it is rapidly converted into vapour, and this vapour, escaping continually from the surface of the water, rises into the air. The quantity of water in the vessel is continually diminished by the quantity thus escaping in the form of vapour, and if the process be continued, the water will altogether disappear from the vessel, being all converted into vapour.

The heat, then, imparted by the fire, in this case, and which fails to augment the temperature of the water in the vessel, is altogether absorbed by the vapour into which the water is converted. This vapour, it is true, is not hotter than the water in which it is formed, its temperature, like that of the water, being 212°; but it is proved by experiments, made in the laboratories of chemists and philosophers, that much more heat is required to impart to

vapour the temperature of 212° than to impart the same temperature to water, and it is in raising the vapour formed from the water to the temperature of the water itself that the entire quantity of heat received from the fire is absorbed.

9. Thus it is found that a given weight of water at 212° when it passes into vapour, absorbs as much heat as would be sufficient to raise five and a half times the same quantity of water from the freezing to the boiling-point.

10. It is not alone when raised to the boiling-point that water is converted into vapour. It is vapourisable more or less at all temperatures, and it has been ascertained that a vapour is produced even from ice. But the evaporation which takes place from water below the boiling-point, is produced in a different manner, and under different conditions. At the boiling-point, water is converted into vapour at all points and at every depth, and most abundantly at those parts where it is in contact with the surface of the vessel upon which the fire acts. But at other temperatures the evaporation is altogether superficial. The vapour is evolved from the surface of the water above, and rises into and mingles with the stratum of air which rests on the surface of the water. This evaporation is also infinitely less rapid and copious than that which is produced by raising the whole mass of water to the boiling-point, and maintaining it at that point.

11. The stratum of air which rests upon the surface of water may be regarded as a medium which has a certain limited power of absorbing the vapour of the water, exactly as a sponge receives liquid water into its numerous pores. The air, like the sponge, has a limited capacity for vapour, and it may become so charged with vapour as to be incapable of absorbing more. The air in this case is said to be *saturated* with vapour.

Evaporation from the surface of water, therefore, takes place more or less freely and copiously as the air is more or less below the point of saturation; and when the air has already attained the point of saturation all evaporation ceases.

12. The process of drying moist or wet objects is an example of the effects of evaporation. The moisture upon the surface, or in the texture or pores of the object is evaporated by exposure to the air, and the object becomes free from moisture, or dry. This evaporation takes place so much the more rapidly as the air is below the point of saturation, and so much the more slowly as it is nearer to that point.

13. Every one is familiar with the fact, that wet roads and footpaths will on some days be dried in a few hours, while on others they will continue wet without any marks of drying. These are mere consequences of the state of the air in relation to

the vapour with which it is charged. In the former case it is under-charged, and therefore readily receives the evaporation from the roads and footways, which accordingly become dry; in the latter it is surcharged, and is at or near its state of saturation; it can receive no more vapour; no evaporation is possible, and the roads remain wet although no rain fall.

14. Washerwomen who spread linen in the air to be dried, well know that the facility of drying it varies on different days. Some days have no drying power, the air being saturated with vapour. Others dry the linen easily and quickly. Then the air is little charged with vapour, and is far below the point of saturation. Between these there are many degrees in which the facility of drying varies.

15. Wind stimulates evaporation, and therefore expedites drying. This is easily explained. So fast as the stratum of air over water becomes charged with vapour and raised towards its point of saturation, it is swept away, and a fresh portion of dry air is brought into contact with the wet surface. This in its turn is swept away, giving place to another dry portion of air, and so on. In this way, all moist objects exposed to wind or currents of air are speedily dried.

Wet objects are quickly dried when exposed to artificial heat, the moisture they contain being rapidly evaporated.

16. Water when absolutely pure is without taste, and insipid. But in its natural state water never is pure. Spring water raised from inferior strata of the ground has always various earthy and saline matters dissolved in it. In fact, every constituent of the strata from which it has been raised, or through which it may have passed, which is soluble in water, is necessarily dissolved in it in greater or less quantity. River water contains more or less of all the soluble constituents which it encounters either at its sources or on the beds and banks of the channels through which it has passed, besides the soluble parts of various dead animal and vegetable matter which it inevitably receives in its course.

17. All water in its natural state contains more or less fixed air mixed with it. This is most commonly carbonic acid. This gas, which is the same as that which effervesces in soda water, lemonade, champagne, and bottled malt liquors, gives to the flavour of water a certain agreeable pungency.

18. Water acquires very various flavours and other qualities, according to the nature of the substances which it holds in solution. Spring water, in general, even when it is most pure, holds lime and silicious earths in solution. It is from these that it acquires the quality popularly called hardness. It will not easily mix with soap, and it is not suited to culinary purposes.

19. Water which is free from this quality, and which holds but

little earthy matter in solution, is called, on the contrary, soft water. Rain water and river water is in general soft, although the latter is never free from some portion of earthy combination.

20. Mineral springs are examples of water holding peculiar mineral salts in solution, in quantities so considerable and of qualities so peculiar as to render it altogether unfit for common use. It acquires, however, from these, peculiar medicinal virtues.

21. Water generally holds suspended in it various impurities which are not dissolved in it. Muddy water is an extreme example of this. But without being actually muddy, water often has many impurities, suspended without being dissolved in it. All such impurities are removed by FILTRATION.

22. In chemical researches, where the quantities of liquid operated on are usually small, a species of paper, called filtering paper, is used. This is white unsized paper, which is formed into a conical bag, and placed in a glass funnel of corresponding shape. The liquid to be filtered is made to pass slowly through the pores of the paper, by which it is strained of the foreign matter suspended in it.

23. The filters used in the arts and in domestic economy for the purification of water have been very various. An open grained stone from Teneriffe was formerly much used for this purpose, as also porous unglazed earthenware. These have been more recently, however, completely superseded by a variety of artificial filtering apparatus, which for the most part consist of strata of gravel, sand, and charcoal powder, through which the foul water is pressed by its own weight, and by which it is very effectually strained of its solid impurities.

24. It has been stated that water is transparent and colourless; and, so far as respects any moderate quantity of the liquid which is submitted to observation, this is true. But, strictly speaking, water is neither absolutely transparent nor absolutely destitute of colour. If we look into the sea, where the water has any considerable depth, we find that its colour is a peculiar tint of blue; but if, however, we take up a glass of the water, which thus appears blue, we shall find it limpid and colourless. The reason of this is, that the quantity of water contained in the glass reflects to the eye too small a quantity of the colour to be perceivable; while the great mass of water viewed when we look into the deep sea, throws up the colour in such abundance as to produce a strong and decided perception of it.

The same is true of all transparent coloured liquids. Sherry in a decanter has a deep golden colour. Seen through the thin stem of a tapering champagne glass it appears paler and paler, until towards the point of the cone it loses all colour.

It is probable that the colour of water arises partly from the

substances which it holds in solution. The fresh water of a lake has a colour different from that of the salt water of the sea. How far the colour of water may arise from the various substances which it holds in solution is difficult to decide, inasmuch as we cannot obtain a sufficient quantity of water absolutely pure to be enabled to ascertain its proper colour.

25. It appears from what has been explained that filtration only disengages from water the solid impurities which may be mechanically mixed with or suspended in it; and if all water in the natural state holds in solution more or less foreign matter, it may be asked how water absolutely pure can be obtained?

It must be observed that, for all ordinary purposes, water chemically pure would be less suitable than such water as is commonly obtained. For alimentary purposes, absolutely pure water would be neither agreeable nor sanitary. For culinary and domestic purposes such purity is not needed.

26. Of all water found in the natural state, rain water is the purest. But this, as commonly obtained, having first fallen on the roofs of buildings, and then passed through pipes and conduits to the reservoirs in which it is collected, takes up and dissolves more or less of the impurities formed upon the surfaces over which it passes. To obtain rain water in perfect purity, it must therefore be received directly as it falls in clean vessels. But even then it is found to be impregnated more or less with air, and especially with carbonic acid, which it absorbs from the atmosphere. Minute portions of ammoniacal salts are also found in it, and if it fall near the sea, it has generally a small portion of common salt in solution. Rain which falls during thunder storms has often traces of nitric acid, formed probably by the effect of the atmospheric electricity.

27. Next to rain water, river water is the purest. The Thames water, where it is not polluted by the drainage of the metropolis, is found to contain no more than two grains of foreign matter in solution in a pint. The matter which it thus holds in solution is principally carbonate and sulphate of lime, common salt, chloride of magnesium, and animal matter. A gallon of Thames water in its most impure state, when properly filtered, does not contain more than twenty-four grains of earthy or saline matter, and in its purest state not less than sixteen grains.

When water is contaminated by animal and vegetable matter, if kept for some time, it undergoes a spontaneous purification, losing its offensive odour and colour, and depositing more or less sediment. Water for the supply of ships is well known to undergo this process of purification by fermentation, and the larger the quantity of destructible matter suspended in it, the more complete and rapid is its purification. A preference is given to Thames

water for marine stores on this account, the more pure river water fermenting less rapidly, and remaining more or less foul and putrid for a much longer time.

For the supply of London, however, where this spontaneous purification is not to be waited for, it is obvious that the water should be taken from that part of the river above Richmond which is beyond the influence of the tides, and where it is not liable to be polluted by the contents of the sewers, the offal of manufactories, and the mud stirred up by steamers.

28. Water was supposed by the ancients to be one of the elements or simple substances of which all others are composed. It was ascertained, however, towards the close of the last century, that it is a compound of two substances as different in their form and properties from water itself as can well be imagined. Water is a heavy liquid. Its constituents are light gases, one of them being the lightest material substance ever yet discovered. Water is an antagonist of fire. One of its constituents is the most highly combustible substance in nature, and the other is a gas whose presence is necessary to fire, and hence called a supporter of combustion. In order to demonstrate the composition of water, it is necessary, in the first instance, to obtain that liquid absolutely pure, and it has been already stated that it is never so found naturally.

29. All fixed air with which water is charged may be dismissed from it by boiling; but to separate it from such matters as it may hold in solution, it must be submitted to the process of DISTILLATION.

30. The principle of distillation is easily explained.

If water which holds in solution any earthy or saline substance be raised to its boiling point, it will be converted into vapour, but the substance it holds in solution will not be so converted. As the water is gradually evaporated, the substance held in solution remaining undiminished, the solution first is rendered stronger and more concentrated, inasmuch as the same quantity of saline matter is dissolved in a less quantity of water. As the process goes on, the entire quantity of water will at length be evaporated, and the earthy or saline matters which it held in solution will remain in the vessel in which the evaporation takes place. This is an experiment which may be tried by any person. Let a tablespoonful of water, in which salt has been dissolved, be held for some minutes over the flame of a spirit lamp. The liquid will boil, and will soon be entirely converted into vapour, the salt alone remaining in the spoon.

31. But when it is the object, as in distillation, to obtain, not the matters held in solution by the water, but the pure water itself *separated from* these matters, it is necessary to prevent the vapour

from escaping, and to reconvert it into water. Now, as water is converted into vapour by heat, so, on the other hand, vapour is reconverted into water by cold. If, therefore, an apparatus be so constructed that as the vapour rises from the boiling water it shall be received into a close vessel where it is exposed to the contact of a cold surface, it will be restored to the liquid form, and being collected in that state, it will be so much pure water; pure, at least, so far as it has been separated from the substances which it held in solution before it underwent the process of evaporation.

32. The vapour of water is many hundred times lighter, bulk for bulk, than water itself. It has resulted from accurately conducted experiments, that a gallon of water evaporated at the temperature of 212° will produce nearly 1800 gallons of vapour. It follows, therefore, that when vapour is reconverted into water by exposure to cold, a very great volume of it will produce a very small volume of water. Thus, to produce a gallon of pure water, we must have nearly 1800 gallons of vapour.

33. It is for this reason that the conversion of vapour into water has been called CONDENSATION, and the apparatus in which such change is produced has been called a CONDENSER. The vapour is condensed, because it is reduced to a bulk 1800 times less, and is, therefore, rendered 1800 times denser and heavier.

The process by which water is first converted into vapour and then restored to the state of water is called distillation, from a Latin word DISTILLATIO, which signifies "falling in drops." The conversion of the vapour into liquid in the condenser usually proceeds so slowly that the liquid falls from the spout of the condenser, not in a continuous stream, but in a succession of drops.

34. In the industrial arts, and in chemical laboratories, where water absolutely pure is needed in considerable quantities, its distillation is conducted in an apparatus which is represented in fig. 1.

This distilling apparatus, or alembic, consists of a copper boiler, A, fixed in a brick furnace, having a dome-formed cover, B, adapted to it, from which a bent tube, *b c d*, proceeds, and is connected with a spiral tube called a *worm*. This worm is inclosed in a large cylindrical cistern, *p q j r*, constructed in metal, and which is kept constantly filled with cold water. The lowest part of the worm passes out of this cistern near its bottom, and terminates at *a*, over the mouth of a jar, *c*, intended to receive the distilled water. An opening, *t*, having a steam-tight stopper, is provided in the boiler, through which the water to be distilled is introduced into it.

The vapour issuing from the boiler through the tube, *b c d*, passes into the worm, being first received by the vessel, O, where the condensation begins.

Passing next through the coils of the worm, it is exposed to the contact of its cold surface, and is entirely condensed and reduced to the liquid state before it arrives at the lower extremity, *a*, from which it trickles in drops into the jar, *c*.

The heat disengaged from the vapour in the process of condensation being constantly imparted to the water in the cistern, *p q j r*, that water would be gradually warmed, and if it were not discharged and replaced by cold water, it would no longer keep the worm cold enough to condense the vapour. A supply of cold water is therefore introduced through a pipe, T T, while the heated water flows away through the pipe of discharge, *o*.

Heated water being lighter, bulk for bulk, than cold water, will float upon the latter without mixing with it, unless the liquid be agitated. The cold water, therefore, being introduced at the lowest part, T, of the cistern, will form the inferior strata, while the heated water will collect at the superior strata, and being pressed upwards by the cold water will flow out at *o*. The supply pipe, *p*, which feeds the pipe, T T, and the discharge pipe, *o*, may be, and generally are, so regulated that the water discharged from *o* is very little below the temperature of the vapour coming from the boiler, while the water of the lowest strata is as cold as the external atmosphere. The vâpour, therefore, which enters at *d*, is at first only partially condensed, the condensation being rapidly increased, as winding through the worm it passes in contact with a surface colder and colder, until, at length, arriving at the lowest coil, it is wholly condensed.

The heated water which flows from the discharge pipe, *o*, may be used to feed the boiler, B; and being already at a high temperature, an economy of fuel is thus effected.

When extreme purity is required in the distilled water, it is evaporated at a temperature lower than 212°, because at that temperature a certain small portion of the foreign matters which it holds in solution sometimes go over in the vaporous state through the worm, and are ultimately deposited in the jar, *c*. The lower the temperature at which the water in the boiler is evaporated, the less of this impurity will pass through the worm.

By these expedients, with proper precautions, water absolutely pure, and entirely free from all foreign matter, may be obtained.

35. It remains now to show how the compound nature of this liquid can be demonstrated, and the characters and proportions of its constituents ascertained.

This may be accomplished by either of two methods; by COMPOSITION or DECOMPOSITION, or, if the Greek derivatives be preferred, by SYNTHESIS or ANALYSIS.

The method by synthesis presumes the previous knowledge of

the constituents, and consists in showing, that by combining these constituents water may be produced.

The method by analysis presumes the previous discovery of some physical agent capable of overpowering the mutual attraction by which the constituents of water are held together, and tearing them asunder, and exhibiting them separated one from the other, so that their characters and properties may be ascertained.

Since the question itself is of the very highest interest and importance, and since both the methods of synthesis and analysis are in themselves most instructive and easily intelligible, we shall here explain them.

36. There are two airs or gases known to chemists, and denominated oxygen and hydrogen.

A general idea of oxygen and its leading properties has been already given in our Tract on Air.

Hydrogen, like gases in general, is an invisible colourless air, which when perfectly pure is without taste or odour. But as commonly produced it is mixed with very minute proportions of impurities, which impart to it a peculiarly disagreeable odour, with which every one is rendered familiar by the occasional leakage of the pipes used for gas-lighting.

37. This gas is the lightest of all material substances, being bulk for bulk more than fourteen times as light as common air.

38. For this reason it is eminently fitted for the inflation of air-balloons. Two thousand cubic feet of this gas will weigh only about 11 lbs., while the same volume of common air will weigh about 160 lbs. A balloon, therefore, which would contain 2000 cubic feet of hydrogen would have a buoyancy or tendency to ascend, amounting to 149 lbs., and if the silk bag, cordage, and car, with its load, have less than this weight, it will have an ascensional force equal to the excess.

39. Hydrogen is one of the most inflammable bodies in nature. It burns with a very pale bluish flame, giving very little light, but intense heat.

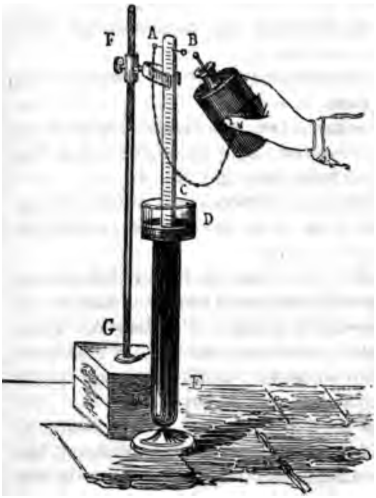
40. If a mixture of oxygen and hydrogen gases be introduced into a strong glass vessel, and be shut into it by closing the stop-cock in the pipe by which the gases are introduced, an electric spark transmitted through the mixture will inflame the hydrogen gas, and an explosion will take place, after which the glass vessel will appear to be filled with vapour, and will acquire an increased temperature. When, after a short interval, it cools, the inside surface of the glass will appear to be bedewed. Water will trickle down the sides. A certain quantity of gas will remain in the vessel. If this gas be examined by the usual tests it will be found that it is no longer a mixture of oxygen and hydrogen, but is one

or the other gas in its separate and pure state. Whether it be pure and unmixed oxygen, or pure and unmixed hydrogen, will depend on the proportions in which the gases were originally mixed in the vessel before the explosion.

41. There are many forms of apparatus by means of which this important experiment may be performed. One of them is represented in fig. 2.

A cylindrical vessel, D E, wider at the top than below, is filled with mercury. A graduated tube, B C, of thick and strong glass, about an inch in diameter, closed at one end, B, and open at the other, C, being filled with mercury and stopped by the hand at the open end, is inserted and plunged in the mercury in the cistern, D E. The mercury will not fall out of B C, because the atmospheric pressure acting on the external surface of the mercury in D E will support it. The gases, oxygen and hydrogen, may now be introduced into B C, by discharging them in the mercury under the open mouth of the tube, B C. They will rise in bubbles through the mercury, and will displace a portion of that liquid in the top of the tube, B C. In this manner any desired proportions of the gases may be introduced into the tube, B C, limited only by the capacity of the tube.

Fig. 2.



Near the top of the tube, B C, two small holes on opposite sides are bored, through which two pieces of platinum wire are inserted, terminating inside and outside in knobs. The inside knobs are close to each other, without being actually in contact. When the knob of a charged electric jar is presented to B, while A is connected by a metallic chain with the outside coating of the jar, the electric discharge will pass between the two inner knobs, and will inflame the hydrogen contained in the tube, B C.

It is in experimental researches of this kind more convenient to express the quantities of the gases by their measures as indicated by the graduation of the tube, B C. It will render this explanation,

however, more easily intelligible to express them by their weights.

Let us then suppose, in the first instance, that 1 grain of hydrogen and 12 grains of oxygen are contained in B C. When the electric discharge is transmitted, the hydrogen inflamed, and the tube, B C, cooled, water and gas, as already stated, will be found in it. If the water be exactly weighed, it will be found to amount to 9 grains, and the gas will amount to 4 grains. If these 4 grains of gas be examined they will be found to be pure oxygen. Thus this residual gas will not be inflammable, but if a lighted taper be plunged in it, the flame will become larger and brighter. In a word, it will have all the properties of pure oxygen, explained in our Tract on Air.

It appears, then, that of the mixture of 1 grain of hydrogen and 12 grains of oxygen, which were in B C before the explosion, the entire grain of hydrogen has entered into combination with 8 of the 12 grains of oxygen, and has produced 9 grains of water, the other 4 grains of oxygen remaining unchanged in B C.

It follows, therefore, that the gases hydrogen and oxygen, being combined in the proportion of 1 grain of the former to 8 of the latter, produce water.

If 2 grains of hydrogen and 8 of oxygen had been introduced into B C, the explosion would still produce 9 grains of water, but in this case the residual gas would be 1 grain of hydrogen. Thus 1 of the two grains of hydrogen, combining with the 8 grains of oxygen, would produce 9 grains of water, while the other grain of hydrogen would remain in its pure and separate state.

If 1 grain of hydrogen and 8 of oxygen had been introduced into B C, the explosion would have converted the whole of the gases into 9 grains of water, and no residual gas whatever would be found in B C.

From all this we must infer that water is a compound liquid, whose constituents are the two gases, oxygen and hydrogen, combined in the proportion of 8 parts by weight of the former to 1 of the latter.

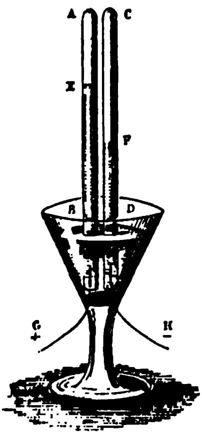
42. It follows, therefore, that one-ninth part of water, the natural antagonist of fire, is the most inflammable of bodies, and the other eight-ninths is a body without whose presence fire cannot exist.

Having thus explained the manner in which water is produced by the combination of its two constituents in due proportion, it now remains to show how the liquid itself may be resolved into its constituent gases.

43. There are several methods of accomplishing this, but the most direct and simple is by submitting water to the action of a voltaic current of sufficient force. It has been proved that the poles of a voltaic battery have specific attractions for different

bodies; the positive pole for some, and the negative for others. Now it happens that of all natural bodies that for which the positive pole has the strongest attraction is oxygen, and one of those for which the negative pole has a strong relative attraction is hydrogen. If, therefore, under certain conditions the two poles be brought to act on water, it may be expected that its decomposition will ensue, the oxygen being disengaged at the positive, and the hydrogen at the negative pole, and this in fact does take place.

Fig. 3.



44. Various forms of apparatus have been contrived for the exhibition of this experiment. The most simple and instructive is represented in fig. 3.

Two small holes are pierced near the bottom of a wine-glass, through which the ends of two wires, G and H, being inserted, so as to rise to the height of an inch or two near each other in the glass, they are cemented in the holes by mastic. These wires are put in connection, one with the positive or + pole, and the other with the negative or — pole of a voltaic battery. Water, slightly acidulated to give it more conducting power for electricity, is then poured into the glass, and two graduated glass tubes, A B and C D, each about half an inch in their interior diameter, being first filled with acidulated water, and being stopped at the open ends by the hand, are inverted and immersed in the glass, one over each of the wires. The water will then be supported in the tubes by the atmospheric pressure.

The electric current will now immediately begin to flow from the extremity of one wire through the water to the extremity of the other, and by its attraction the water will be decomposed, the oxygen constituent being attracted to the extremity of the positive, and the hydrogen to that of the negative wire. These gases will be therefore disengaged at the points of the wires as if they issued from them, as they would from small apertures in vessels containing them. They will be seen rising rapidly in small bubbles in each of the tubes, in the upper parts of which they will collect, displacing the water and pressing it downwards. After a short time, the tube containing the negative wire will be filled with gas, the water being totally expelled from it from the top to the level of the water in the glass, and at the same time the tube over the positive wire will be half filled.

Thus it appears, the tubes being of equal capacity, that the volumes of the two gases produced are in the proportion of 2 to 1, the volume of hydrogen being twice that of oxygen.

It will be further observed, that continually throughout the process of the experiment, the same proportion is maintained between the volumes of the gases evolved. At every stage of the process, the volume of hydrogen, C F, evolved, is found to be exactly double that of the oxygen, A E.

But a comparison of the weights of these two gases, bulk for bulk, proves that oxygen is sixteen times heavier than hydrogen. It follows from this that the weight of the double volume of hydrogen evolved in the experiment here described, will be exactly one-eighth of the single volume of oxygen simultaneously evolved.

Thus it appears that the water is decomposed by the voltaic current, and that its constituents are the gases oxygen and hydrogen, in the proportion of 8 parts by weight of oxygen to 1 of hydrogen.

46. Certain metals which are obtained in the laboratories of chemists, though unknown in the arts, such as potassium and sodium, have so strong an attraction for oxygen that they cannot be exposed in the atmosphere without spontaneously combining with that constituent of it. If a piece of one of these metals be plunged in water, it will exert an attraction on the oxygen of the water so powerful as to separate it from the hydrogen. The oxygen will, in virtue of this attraction, desert the hydrogen, and, combining with the potassium or the sodium, will form potash or soda, while the hydrogen, disengaged in the form of gas, may be collected in a glass receiver in the usual way. If the potash or soda thus produced be weighed, it will be found to be heavier than the potassium or sodium, by the weight of the oxygen which has entered into combination with it, and this excess of weight will be exactly eight times the weight of the hydrogen which is disengaged; from which it follows as before that water consists of 8 parts by weight of oxygen and 1 of hydrogen.

47. None of the metals commonly used in the arts have an attraction for oxygen sufficiently energetic to effect thus spontaneously the decomposition of water. The attraction, however, of some of them—iron, for example—may be so exalted by elevation of temperature that it may, by means of certain arrangements, produce a like effect.

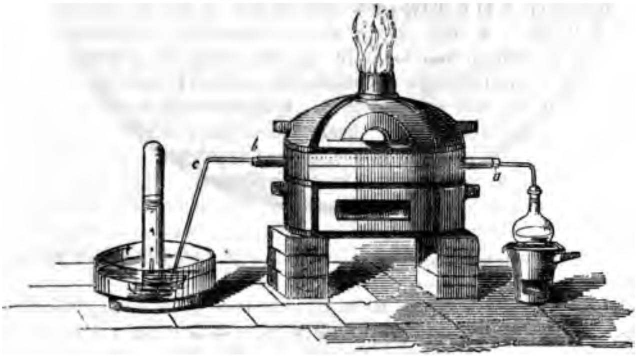
An apparatus for the decomposition of water, by means of heated iron, is represented in fig. 4.

A porcelain tube, *a b*, the middle part of the length of which is filled with fragments of fine iron wire, is inserted across a furnace, by means of which the tube may be heated, so that the iron it contains shall be red-hot. One end, *a*, communicates by a

rectangular tube with a glass vessel containing water, placed upon a charcoal fire, or supported over a spirit lamp. The other end, *b*, communicates by a bent tube, *b c d*, with a glass tube filled with water, inverted and immersed in a capsule or dish containing water. The water is supported in the tube, as in the former experiments, by the atmospheric pressure. If gas issue from the mouth of the tube, *d*, which is bent under that of the wide tube containing the water, this gas will rise in bubbles, displacing the water in the top of the tube.

These arrangements being made, and the iron contained in the tube, *a b*, being rendered red-hot, the water in the glass vessel is made to boil. The vapour proceeding from it entering the tube *a b* at *a*, forces its way through the interstices of the red-hot iron wire; there it is decomposed, the iron attracting the oxygen,

Fig. 4.



with which it combines, forming a substance called the *oxide of iron*, which is familiarly known as *rust*. The hydrogen alone issues from the tube at *b*, and passing through *b c d* rises into the large tube, displacing the water, as represented in the figure.

When a sufficient quantity of gas is collected, its weight is ascertained, and also the increase of weight imparted to the iron wire in the tube, *a b*, by the oxygen which has been combined with it, and it is always found that the latter is exactly eight times the former.

Thus we still find the same remarkable fact reproduced in various forms. The rusted wire is heavier than the original clean wire by the weight of the oxygen which it has attracted from the aqueous vapour, and which, combining with it, forms the rust; and this weight is eight times that of the hydrogen from which it has been separated, showing as before that water *consists of* 8 parts by weight of oxygen and 1 of hydrogen.

Fig. 11.—THE CELEBRATED CUP OF ARCESILAUS, IN PLAN, WORK OF THE CYRENIAN POTTERS CONTEMPORARY WITH PINDAR, 500 B.C.

THE POTTER'S ART.

CHAPTER I.

1. Antiquity and general estimation of the art.—2. Its materials and their treatment.—3. Potter's wheel.—4. Allusions to the art found in ancient writers.—5. Ancient drawings in Theban catacombs.—6. Processes of potters 1900 B.C.—7. Homer and the potters of Samos.—8. Ancient tombs containing pottery excavated near Naples.—9. Proofs of their antiquity.—10. Campanian sepulchral chamber with pottery.—11. German sepulchres.—12. Cup of Arcesilaus.—13. Ancient Greek potters.—14. Chinese traditions of pottery.—15. Chinese pottery found at Thebes.—16. Porcelain works of King Te Tching.—17. Processes practised there.

1. After the fabrication of weapons for personal defence and the procuring of food, and that of some rude species of clothing, the formation of vessels from baked clay is the most ancient

of industries; and it is worthy of note, that, simple as were its original processes and rude its primitive productions, no art has more ministered to luxury; none has produced more gorgeous specimens of ornamentation; in none does the value of the finished article bear so enormous a ratio to that of the raw materials; none has so steadily and continuously advanced and improved with the progress of knowledge; none is more largely indebted to the resources and discoveries of science; nor has any more constantly received the homage of the great and the admiration of mankind in all countries, and especially in those which have attained the highest condition of civilisation and refinement.

2. The materials of the potter are certain sorts of clay which possess the property, when moistened with water, of acquiring the consistency of dough. This dough being shaped into the desired form, the water which gave it softness and plasticity is expelled from it by evaporation, produced by exposure in ovens to intense heat. The article is thus rendered hard and strong, so as to retain its shape, and to resist fracture from slight causes.

In this state however, the surface is rough and the material is porous, so that it would imbibe any liquid in which it might be immersed, or which might be poured into it. To give it a more brilliant surface, and to render it impervious to liquids, it is therefore covered with a thin coating of some vitrifiable matter, which being exposed to the action of fire, is converted into a skin of glass. This gives increased beauty to the article, and at the same time renders it impermeable by liquids, and enables it also to resist their chemical action.

The ornamentation of the article is produced either by the beauty of form imparted to it, or by figures in relief produced by moulds pressed upon it while yet soft, and before the process of baking; or, in fine, by designs painted in colours either upon the surface before glazing, or upon the glaze. In either case the colouring-matter is submitted to the action of fire, and the process has more or less of the character of enamelling.

The plastic clay of the potter does not usually exist in its pure state in the earth. It is found, on the contrary, like the metals, mixed, or chemically combined, with many heterogeneous substances, from which it is separated by a variety of complicated processes.

When it is reduced to a sufficient degree of purity, it is necessary to mix with it such a proportion of water as will convert it into a dough of a certain consistency. This is a process of some difficulty and labour, for the water will at first be unequally

diffused through the mass, one part being too plastic and another part not sufficiently so. The whole is reduced to an uniform consistency by the process of kneading, in a manner exactly similar to that by which the dough of flour is treated in bread making; and, as in this latter case, the method most commonly adopted for effecting this is by treading the dough with the feet. This, indeed, is one of the most characteristic operations of the potter, being quite inseparable from his art, to whatever objects it be applied, from the making of common bricks to the fabrication of the most splendid porcelain.

The mass of dough being spread out upon a flat surface of stone or wood, the potter walks upon it with his naked feet, beginning from the centre of the cake, and following a spiral course until he reaches the circumference, after which he returns by the same spiral to the centre.

When the proper consistency and homogeneity are thus imparted to the dough, the next process is to give it the form of the articles intended to be fabricated. This is effected by different methods, according to the shape desired; but as by far the greater number of articles of pottery are round in their horizontal dimensions, the method most common is as follows:—

A ball of the dough, sufficiently large for the article to be formed, is laid upon the centre of a small horizontal circular disc of plaster of Paris, supported on a circular stage or table which rests on a central pillar fixed in pivots, so as to be capable of receiving a motion of rapid rotation. This motion being imparted to the ball of dough placed upon the table, the potter applies his hands to it, and gives it the desired form by the gentle pressure of his palms and fingers. The process resembles in all respects that of turning with the lathe, only that the revolving shaft is vertical instead of being horizontal. The rude and soft mass of dough assumes, under the dexterous fingers of the potter, the most symmetrical and beautiful forms with marvellous facility and celerity.

3. This apparatus, called the "Potter's-wheel," is of high antiquity, being indeed co-eval with the art, and has had very nearly the same form and arrangement in times the most ancient and the most modern, and in parts of the earth most remote from each other, and often among people between whom there are no traditions of intercommunication.

The custom which prevailed in the earliest ages and in all countries of consecrating certain articles of pottery to religious uses, and depositing them in sarcophagi and in tombs, sometimes with drawings representing the processes of their fabrication, proves the veneration in which the art was held, and has happily

also been the means of bringing to the knowledge of modern times its early history.

The antiquity of the art is also attested by the frequent allusions to it in poetic writings of remote date. These allusions, in many cases, incidentally disclose the processes of the art, and prove their almost exact identity with those of the present age.

4. Every one is familiar with the frequent metaphors and comparisons taken from the processes and productions of the potter in the Hebrew Scriptures.

"The Lord said to Jeremiah—arise and go down to the potter's house. Then I went down and behold he wrought a work on the wheels. And the vessel that he made of clay was marred in the hand of the potter; so he made it again another vessel, and the Lord said, O house of Israel, cannot I do with you as this potter? Behold, as the clay is in the potter's hand so are ye in mine."—*Jer.* xviii. 1—6.

"I will break this people and this city as one breaketh a potter's vessel." —*Jer.* xix. 11.

The antiquity of the process of kneading the dough with the feet is proved by many allusions to it in the ancient writers.

"I have raised up one from the north, and he shall come: from the rising of the sun shall he call upon my name, and he shall come upon princes as upon mortar, and *as the potter treadeth clay*."—*Isaiah*, xli. 25.

In ancient Greek and Latin authors allusions are frequent.

Homer, describing the shield of Achilles, compares a dance by figures forming a ring upon it, as having as much precision and rapidity as the wheel of a potter put in motion by his hands.—Iliad, xviii., 599—600.

For the more common sorts of ware, the potter still imparts, in many cases, the motion to the wheel with his hands.

The wheel, however, is more generally moved by the feet, and often by an assistant, or even by steam or other moving power, when many of them are required to be kept in motion.

In Plautus we have—

"Vorsutior es quam rota figularis."—3 Epid. ii. 35,

"Thou turnest more rapidly than a potter's wheel."

"——Amphora cæpit
Institui: *currente rotâ* cur urceus exit?"—Hor. Art. Poet. 21.

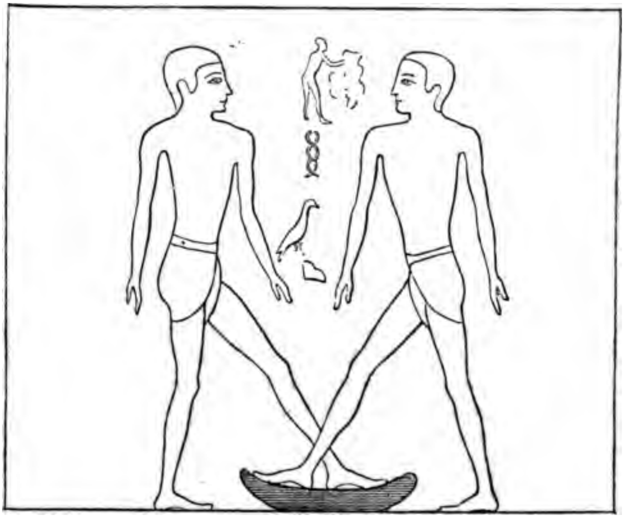
"A large vase was designed: why, as the wheel revolves, turns out a little pitcher?"

"——Testa alta paretur
Quæ tenui muro spatiosum colligat orbem:
Debetur magnus patinæ, subitusque Prometheus.
Argillam, atque rotam citius properate: sed ex hoc
Tempore jam, Cæsar, figuli tua castra sequantur."
Juvenal, Sat. iv. 131.

ANCIENT POTTERY.

"No, let a pot be formed, of amplest size,
Within whose slender sides the fish, dread sire,
May spread his vast circumference entire!
Bring, bring the tempered clay, and let it feel
The quick gyrations of the plastic wheel:
But, Cæsar, thus forewarned, make no campaign,
Unless your potters follow in your train."—GIFFORD.

Fig. 1.



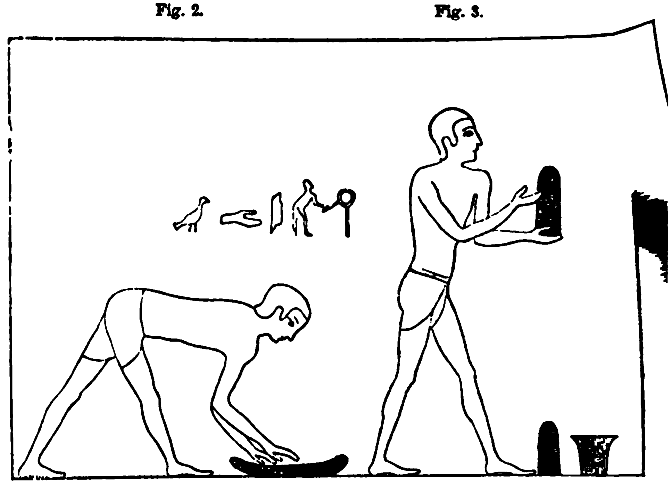
5. In the catacombs of Thebes and Beni-Hassan, which have been proved to have existed nineteen centuries before Christ, and therefore 3700 to 3800 years from the present time, drawings have been discovered, exhibiting, in a great variety of forms, the processes of the potter's art as then practised. The annexed engravings (fig. 1 to 5) have been copied from paintings discovered in the catacombs of Thebes, and described by Champollion. They exhibit the processes of the potter, from the kneading of the dough by the feet to the removal of the baked article from the oven.

6. Fig. 1 represents two potters kneading the paste by the process of treading. The hieroglyphics signify "he treads."

Fig. 2.—A man taking up the dough to form it into a mass for the wheel. The hieroglyphics express this action.

Fig. 3.—The same man taking the ball, or prepared mass, to the potter who works at the wheel.

Fig. 2. Fig. 3.



Figs. 4 and 5.—Two potters shaping an article on the wheel. The vessel which stands between the wheels, and which also appears in fig. 3 in a water-pot, in which the potters occasionally dip their fingers to regulate the moisture of the dough.

Fig. 4. Fig. 5.

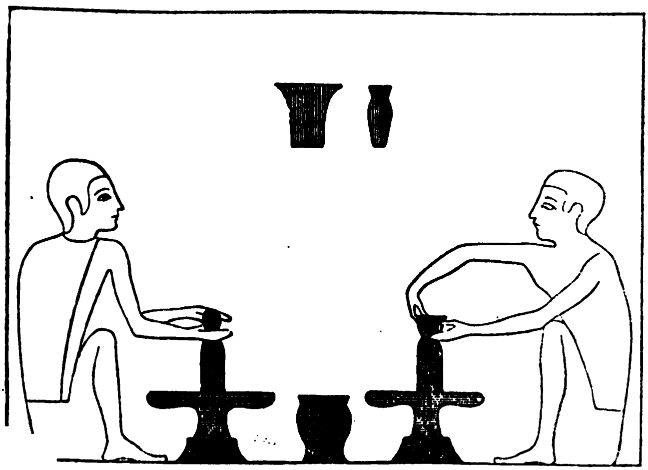


Fig. 6. Fig. 7.

This painting does not show how the wheel is turned, but in another the potter is represented giving with his left hand the motion of rotation to the wheel. When this motion, by the repeated action of the hand, acquires a sufficient rapidity to be continued without further impulse, both hands are applied to the dough, as represented in the figures.

The potter (fig. 4) forms a ball of the magnitude necessary to make a cup. The potter (fig. 5) forms the outside of the cup by the pressure of his first finger, and the inside by his thumb. Every one who is familiar with the action and attitude of a potter working at the wheel, will recognise the peculiar position and rounding of the arm in fig. 5. If the modern potter had served his apprenticeship to him of 2000 B.C., the resemblance could not be more exact.

A cylindrical oven, C, is represented in fig. 6. The attendant, A, is feeding the furnace beneath it with a stick of wood; the flames, D, which play around the cases containing the articles to be baked are seen issuing from the top of the oven.

Fig. 7, represents the oven after the baking has been completed and the fire extinguished, the fire-door of the furnace being on the other side. The potter, B, is in the act of taking out the articles baked, and handing them to another, A, who piles them

in heaps, one of which appears at his feet. The hieroglyphics signify "He takes them out."

In the original paintings from which these drawings were taken the masses of dough in fig. 1 to 5, have a dark grey colour. The articles of baked pottery in fig. 7, have the reddish colour which characterises the ancient Egyptian pottery.

It appears, therefore, from these remarkable paintings, that in all its essential processes, the art of pottery, 4000 years ago, was nearly what it is at present.

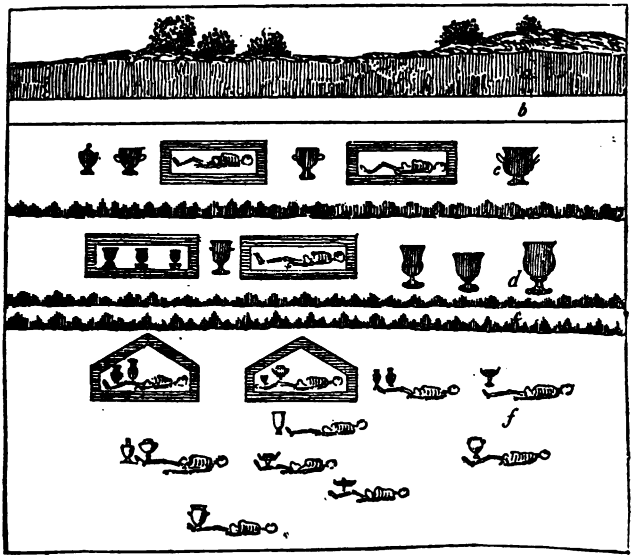
7. It is related in a life of Homer, attributed to Herodotus, that the poet when blind happened one day to pass near the celebrated potteries of Samos. The potters addressed him, and requested him to compose a poem on their art, offering him, as a reward, a selection of their vases. Homer accepted their offer, and composed for them the hymn called the Furnace, still extant, in which are described with singular felicity and exactitude the qualities and excellences of the vases fabricated by these artisans, and the accidents to which they are exposed in the process of baking. These incidents of the oven and their effects have counterparts so exact in the processes of the present day, that the reader of Homer's lines might well imagine that the poet had visited a Staffordshire pottery.

Thus it appears that in Homer's time, that is about nine or ten centuries before Christ, the potters of Samos had already risen to some celebrity. According, however, to the researches of some antiquarians, and their arguments founded on the results of excavations made near Naples, known to have been the place where ancient Greek colonists had established themselves, this art must have been cultivated in Greece in times much more ancient than the Homeric age.

8. The Abbé Mazzola has described and delineated, with elaborate minuteness, the position of tombs and skeletons found in excavations made in Campania. Beneath a stratum of vegetable mould, having a depth of about forty inches, and forming the richly fertile soil for which that tract of country is so celebrated, is found a stratum of white sandy earth, mixed with pummice stone, hard and impenetrable by water. This stratum, which is called *terra maschia*, has a thickness of about twenty inches, and beneath it is a third stratum about thirty inches thick, composed of good black mould. It is beneath this last stratum that the skeletons, sarcophagi, and accompanying vases were found.

A vertical section of the strata, showing the position and arrangement of the skeletons and vases, in a part of the Campania, near Nola, copied from the Treatise of Dubois Maisonneuve, on *Antique* Vases, fol. 1817, is given in fig. 8.

Fig. 8.



The vases and skeletons were found at different depths and differently disposed. In some cases the vases alone were found, as at *d*; in others, the skeletons without, in others, included in sarcophagi; but in all cases the skeletons were accompanied by vases.

9. The Abbé Mazzola maintains, that notwithstanding the presence of pumice stone in the second stratum, it cannot be regarded as the direct result of volcanic action. He concludes that the superficial stratum of fertile earth is of comparatively recent formation, and that at a remote epoch the second stratum of *terra maschia* must have been superficial. Now, as the deposition of the bodies and vases under the *terra maschia* must have preceded the commencement of the formation of the present superficial stratum of vegetable soil, and as the formation of this stratum must have occupied a long succession of ages, he argues that the vases found below the *terra maschia* must have a date long anterior to that of Homer. He adds, in support of this inference, that these vases represent scenes which have never been alluded to, or described by Homer or succeeding poets, such as the combat of Neptune and Ephialtes; that these skeletons found at Nola are always

Fig. 9.

buried immediately in the ground, while elsewhere, as for example, at Avila, they are included in sepulchres; that the inscriptions on the vases are written in the primitive Greek, to be read from right to left, like Hebrew and other oriental languages; and, in fine, that the lateness of their discovery is to be explained by the fact that the strata beneath which they were deposited consisted of stone not used for building by the Romans, but used for that purpose in modern times.

A more distinct notion of the disposition of vases in the ancient tombs may be obtained from the drawings, on a larger scale and with more detail, given by d'Hancarville and other antiquarian writers.

10. As an example of a Campanian sepulchral chamber, we give fig. 9, representing a tomb discovered in the neighbourhood of Naples, showing the relative position of the body and the vases.

11. In fig. 10 is represented the tomb of a German family, including two skeletons with urns, found in the excavation of a tumulus at Unterwelden, near Oberfarrenstadt.

'2. Most of the numerous Greek vases which have been recovered odern excavations, belong to the sixth or seventh century before

Fig. 10.

Christ, and to later dates. Specimens of these were already rare and much prized in the time of Julius Cæsar.

Among the most admired and interesting of these may be mentioned the celebrated cup of Arcesilaus. This vase is represented in plan in fig. 11, (p. 113), and in elevation in fig. 12. It is preserved in the Bibliothèque Royale, now (December, 1853) Impériale. Its height is 10 inches, and its diameter 11 inches.

This cup which was found at Vulci (Camino), in Etruria, represents Arcesilaus, King of Cyrene, seated on the deck of a vessel, the crew of which are engaged, under his superintendence, in weighing baskets of asafœtida, and depositing them in the hold.

This vase is considered to be the work of Cyrenian potters contemporary with Pindar.

13. The names of about forty of the most celebrated potters of Greece have been recorded in the works of philosophers, historians, and poets. Among these the following may be mentioned:—

Dibutades, of Sicyon, whose works were brought to Corinth, where they were preserved. The epoch at which this potter flourished is unknown.

Corœbus, of Athens, flourished in the time of Cecrops, fifteen centuries before Christ. He was reputed to have been the inventor of pottery. It will, however, be shown hereafter that this art was practised in the East at least a thousand years earlier.

Talos, the son of Perdix, sister to Dædalus. This personage

Fig. 12.

was reputed to be the inventor of the potter's wheel. Other mechanical inventions were also ascribed to him, among which were the saw, the chisel, and the compasses. He was said to have taken the idea of the saw from the back-bone of a fish. His skill was said to have excited so violent a jealousy on the part of his uncle Dædalus, that the latter having enticed him to the Temple of Athena, on the Acropolis, flung him headlong from its summit. The goddess of the shrine, however, caught him in his fall, and metamorphosed him into a bird, to which she gave the name PERDIX, *the Partridge*.

THERICLES, of CORINTH. According to Theophrastus, this celebrated potter invented a composition consisting of a black paste susceptible of an high polish, which was much prized. He gave his name to a certain sort of vases called THERICLEAN.

Some scholars have, however, questioned his existence altogether, contending that the name of the vases was derived from their style of ornamentation, which included the representation of animals, θηρία, Theria.

As in modern times, the most eminent sculptors supplied models and designs to the Greek potters. Among these may be named PHIDIAS, POLYCLETES, and MYRON.

14. The Chinese traditions carry back the practice of the potter's art to a very remote epoch. Father Entrecolles, a French missionary, resided in China at the beginning of the last century, and his letters published in Paris, in 1741, supply some curious and resting information on this subject. Writing in 1712, he that at that time ancient porcelain was very highly prized, and rge prices. Articles were extant which were reputed to have

Fig. 13.

Fig. 14.

Fig. 15.

belonged to the Emperors YAO and CHUN, two of the most ancient mentioned in the Chinese annals. YAO reigned in 2357 and CHUN in 2255 before Christ. Other authorities place the reign of CHUN in 2600 before Christ. It appears from the researches of M. Stanislaus Julian that, from the time of the Emperor HOANG-TI, who reigned 2698 to 2599 before Christ, there had always existed a public officer bearing the title of the Intendant of Pottery, and that it was under the reign of Hoang-ti that the potter's art was invented by KOUEN-OU. It is also certain that porcelain, or fine pottery, was common in China in the time of the Emperors HAN, 163 B.C.

In digging the foundations of the palaces, erected by the dynasties of Han and Thang, from 163 B.C. to 903 A.D. great quantities of ancient vases were found which were of a pure whiteness, but exhibited little beauty of form or fabrication. It was only under the dynasty of SONG, that is to say, from 960 to 1278 A.D., the Chinese porcelain began to attain a high degree of perfection.

15. Further evidence of the antiquity of the potter's art in China as well as of the existence of intercommunication between that country and Egypt, is supplied by the discoveries of Rossellini, Wilkinson, and others, who found numerous vases of Chinese fabrication, and bearing Chinese inscriptions, in the Tombs at Thebes. Professor Rosellini found a small vase of Chinese porcelain with a painting of a flower on one side, and on the other Chinese characters not differing much from those used at the

Fig. 16.

present day. The tomb was of the time of the Pharaohs, a little later than the eighteenth dynasty.

This vase, with its Chinese inscription, is represented in fig. 13, from an exact cast made by Mr. Francis Davis.

Another of the Chinese vases, found in the Theban tombs, is represented in fig. 14. This is preserved in the Museum of the Louvre. The shape of the vase is that of a flat-sided flask. A side view is given in fig. 15.

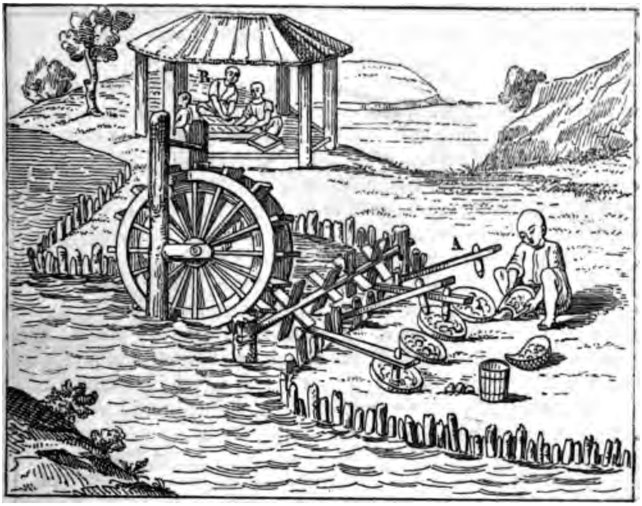
These flasks are very small. The engravings represent them of their proper dimensions. Mr. Wilkinson thinks it probable that they were brought to Egypt from India, the Egyptians having had commercial relations with that country at a very remote epoch, and that they came not as pieces of porcelain, but as vessels containing some article of importation.

16. Among the articles seen at the Great Exhibition, in the Chinese department of the Crystal Palace, was a complete collection of the various materials employed at the great Porcelain Works of King Te Tching. This collection consisted of the plastic clay of which the Chinese porcelain is formed, and of the various colouring matters with which it is decorated.

The place from which these specimens were sent is one of the ancient and celebrated of the porcelain manufactories still

POTTERIES OF KING-TE-TSCHIN.

Fig. 17



existing in China. Father Entrecolles, already quoted, who resided there in 1712, stated that, at that time, there were in operation there not less than 3000 ovens, which gave to the town at night the appearance of one vast furnace with numerous chimneys. He describes the earths of which the china was made as of two kinds, called Kaolin and Petung-tse. These were brought to King-Te-Tschin in the form of bricks from the quarries where the raw material is found.

The process by which these raw materials of the Chinese potter were at that early period prepared in the quarries differed very little from those by which the like materials are prepared for our potters at the present day, and some of the contrivances which have been claimed as modern inventions are merely reproductions of what have been for ages in use in the East.

17. Some details of these processes, as they were practised in China nearly two centuries ago, will be not less instructive than amusing.

The process of quarrying the petung-tse is represented in fig. 16. The mineral is detached in lumps with the mallet and pick-axe. Two of the miners are employed at the sides of the quarry, while a third is getting the mineral from its roof, which is supported by a number of upright posts. A fourth workman is

carrying the produce of the labour of the others to the pounding or crushing-mill represented in fig. 17. The water-wheel acting upon the rectangular arms projecting from the shaft keeps the latter in constant revolution. These arms act upon a series of levers, to the opposite ends of which are attached stone sledges faced with iron. By the action of the wheel upon the short arms of the levers, the long arms carrying the iron-shod stone hammers are alternately raised and let fall. Beneath each of them is placed a trough filled with the rough lumps of petung-tse, which are thus pounded until they are reduced to powder. A man sits near them collecting their contents when pulverised, which he carries in buckets to a large reservoir of water represented in fig. 18, (p. 129), where being thrown, it is strongly agitated until it comes to be well mixed with the water. The mixture thus produced being allowed to remain quiescent for some moments, the grosser and heavier parts of the mineral dust sink to the bottom, and a cream-like liquid remains. This last is then removed in buckets and brought to another reservoir, shown in the drawing, into which it is thrown and agitated as before.

Fig. 18.—ANCIENT CHINESE DRAWING OF THE METHOD OF PREPARING THE PORCELAIN CLAY FOR FABRICATION.

THE POTTER'S ART.

CHAPTER II

1. Processes of Chinese.—2. Their materials.—3. Petungse and kaolin. • 4. Kneading and throwing.—5. Ovens.—6. Majolica in Spain.—7. Italian Lucca della Robbia.—8. Altar-screen by him.—9. Process of fabrication.—10. Productions of Italian potters.—11. Royal presents.—12. Decline of the art in Italy.—13. Pottery in France—Bernard de Palissy.—14. His character, persecution, and death.—15. Palissy and Henry III. in the Bastille.—16. Style of his productions.—17. La belle Jardinière.—18. Origin of the Staffordshire potteries.—19. Discovery of salt glaze.—20. Messrs. Elers.—21. Astbury discovers the use of flints.—22. Origin and character of Josiah Wedgwood.

1. The grosser parts of the mineral which sink to the bottom of the first reservoir, are then brought back to the crushing-mill, fig. 17, and are again submitted to the action of the hammers, and the same process is repeated at the trough, fig. 18.

The cream-like liquid thrown into the second reservoir being

allowed to stand for a sufficient time, all the fine matter suspended in it at length subsides to the bottom, the water becoming clear above. This water is then allowed to flow off, when a stratum of fine and pure petung-tse is found on the bottom of the trough. This is then consolidated and formed by moulds, as represented in the background of fig. 17, into bricks, in which state it is sent to the potteries.

2. This mineral substance, which plays a part so important not only in the Chinese potteries, but in those of other nations, is a variety of that which mineralogists have called felspar, having a slight admixture of quartz.

3. The PETUNG-TSE thus prepared is a white substance of the finest imaginable grain, about two and a half times heavier than water.

The other material used in the formation of the dough or paste, of which the Chinese make their porcelain, called KAOLIN, is found in very deep strata of some of their mountains, and took its name from a mountain near King-Te-Tschin, where the first vein of it had been discovered, which was the origin of the great pottery works established at that place.

The manner of working and purifying the kaolin and forming it into bricks for the potter, does not differ in any important particular from the treatment of petung-tse already described.

Kaolin, when submitted to chemical analysis, proves to be a compound body whose constituents are silica, and alumina, or the pure earth of clay combined with small proportions of magnesia, potash, soda, and iron.

The earths called kaolin or china clay include these constituents in very different proportions as found and used in different countries. That used in the fabrication of the old Chinese porcelain contains 76 per cent. of silica, from 10 to 17 per cent. of alumina, and small proportions of magnesia, potash, and soda.

The Chinese consider that it is to the kaolin that the ware owes all its strength. They call it the *nerve* of the porcelain, meaning probably the plasticity of the paste and its power to resist the intense heat of the furnace. Hearing of the attempts of the European potters (before their discovery of china clay) to make porcelain of petung-tse or felspar alone, they ridiculed the attempt, observing that "they might as well attempt to make a body of flesh without bones."

This alludes plainly enough to the comparatively easy fusibility of petung-tse, and the infusibility of kaolin by the porcelain furnaces, and it would even indicate the probability that the Chinese themselves had tried and abandoned the manufacture of porcelain without kaolin.

Fig. 19.

The ingredients of which the paste is formed being thus supplied to the potter, the process of the formation of the paste from the bricks is also described by Entrecolles as practised in his time.

The bricks of kaolin and petung-tse being again pulverised are further purified by washing, and any sandy matter they may contain removed. The two materials are then mixed in different proportions according to the sort of porcelain intended to be fabricated.

4. The laborious process of kneading the dough is represented as being executed by buffaloes in fig. 19, copied like the others from contemporary drawings.

This method of kneading is still used in China. M. Chavagnon, who penetrated into the interior of that country, assured M. Brongniart, the director of the Sèvres manufactory, that he witnessed the process.

The paste being prepared thus for the fabrication of the porcelain, the process of forming the articles at the potter's wheel as practised at the same epoch in China, is represented in fig. 20.

The wheel is kept in rotation by a man, who holds the ends of a flat strap, which he presses lightly against the edge of the wheel when he impels it by drawing one end of the strap, and

Fig. 20.

yielding to its motion at the other end. After each impulse the strap is loosened and restored to its first position on the edge in order to repeat the impulse. The strap is prevented from slipping over the surface of the edge of the wheel by pins or points projecting from its surface.

The potter places the paste to be formed into the desired article on the head of the wheel, and shapes it with his hands and fingers.

Another man is represented carrying away the finished articles to the oven.

5. The ovens and the process of baking are represented in fig. 21. A man in a shed on the left is employed in placing the articles to be baked in cylindrical cases of baked earth, which correspond to those which our potters call SAGGERS.

An empty oven is represented at A, where a man receives the saggers filled with the articles to be baked, and arranges them in the oven. When the oven is thus filled it is closed by brickwork. A second oven thus filled, and bricked up, is represented at C.

The fire doors or feeding mouths of the furnaces, by which the ovens are heated, appear at D, and the openings for the escape of smoke and the products of the combustion are represented at *a*, *b*, and *c*.

Fig. 21.

The Chinese ovens used at the present time do not differ much in form or arrangement from those designed and described by Entrecolles in the beginning of the last century. M. Chavagnon, who witnessed their performance at a recent period, says that the construction of the flues is so well managed, that the distribution of the heat is sensibly uniform, the ovens such as A, which are most remote from the furnace, being as effectually heated, and the articles in them as well baked, as those, such as C, which are nearest to it.

6. The first attempts made in Europe to fabricate a hard earthenware covered with a glaze, are ascribed to the Moors of the Spanish Peninsula. After this, a manufacture upon a large scale, was established in the Balearic Isles; and the wares originally produced there, and subsequently reproduced in Italy, acquired the name *Majolica*, being a corruption of Majorica or Majorca, the principal island of the Balearic group.

7. The first of the improvers of this art after its importation into the Italian peninsula, was Lucca della Robbia, a Florentine sculptor, whose name has thus become inseparably associated with the history of this ornamental industry. This celebrated artist, born in 1388, died prematurely in his forty-second year. He left, nevertheless, an immense number of works, which have come down to the present times, and are highly prized.

He was succeeded by his brothers and their descendants, all of whom continued, for nearly a century and a half, to practise the art on a large scale, so that it must be always difficult,

if indeed it be possible, to ascertain what are the genuine works of the great artist, and to distinguish them from those of his family, some of whom worked under and with him during his lifetime.

The productions of this family of artistic potters are formed of a paste, consisting of about 50 per cent. of silica, combined with 15½ per cent. of alumina and 22½ per cent. of lime, with small proportions of carbonic acid, magnesia, and iron. The decorations were figures in relief, variously coloured with yellow, produced by lead and antimony, a dark opaque blue, the green produced by copper, and a bad violet produced by manganese. The art of producing colours by means of gold was not then known in Europe.

8. In fig. 22 is represented an altar-screen by Lucca della Robbia. This consists of four pieces and two pilasters. The ground is a fine azure blue; the figures are white; the fruits, cup, &c., in gold-yellow, and the garlands green. The thickness of the earthen ware or *faiençe*, of which it is composed, is little more than an inch and an half. This piece is preserved in the Cabinet SAUVAGEOT.

9. The paste used at this epoch not having the whiteness of the finer porcelain, the articles fabricated were covered with an opaque glaze of some particular colours, by which the coarse and ill-coloured ground of the porcelain was concealed. The process by which these opaque glazes were produced was nearly the same as that by which the transparent and colourless glazes of the present day are produced. The baked article, which before it is glazed is called biscuit, is submerged in a vessel containing the vitrifiable matter, mixed with such a proportion of water as to give it a creamy consistency. After immersion, a coating of this liquid adheres to the surface. The water which holds the vitrifiable substance in suspension is partly imbibed by the material of the vessel. The vessel, thus coated, is placed in an oven, and again exposed to the action of heat of sufficient intensity to vitrify the coating with which it is invested, so that, when withdrawn from the oven, the coating is converted into a coloured and opaque glass, and the vessel is glazed. Sometimes the article, before being baked, was covered with a coat of earthy matter, not vitrifiable but opaque, by which the coarse surface of the paste was concealed, and this coat being hardened in the oven, a transparent glaze was put over it.

10. The majolica ware of Italy was in its most flourishing state from 1540 to 1560. It was during this interval that the finest table-services were produced. The chief places of its fabrication tel Durante and Florence; but its celebrity and the

Fig. 22.

ALTAR SCREEN BY LUCCA DELLA ROBBIA.—1400 A.D.

general taste for it increasing, all the principal Italian cities produced it, and all the most renowned artists, including Raphael himself, supplied designs for it, which potters scarcely less renowned, executed.

It has been often stated that Raphael himself worked at this art. Such, however, was not the fact. The Duke of Tuscany, Guidobaldo II., who extended to this art the most magnificent patronage and encouragement, procured designs from Raphael and his pupils, which he gave to the potters whom he had established at Pesaro to execute; and it happened that among the most skilful of the decorators of these potteries there were two who

bore the name of Raphael. Hence the productions were said to be those of Raphael; and, at a later period, those who were unacquainted with these circumstances concluded that they were the immediate work of the celebrated painter.

11. It was at this time that the celebrity of such productions, and the universal admiration which they excited, produced the custom, continued to the present time, of offering them as royal presents by sovereign to sovereign. The Duke Guidobaldo caused to be executed at Pesaro magnificent services, which he presented to sovereigns and other eminent personages. The splendid service is especially mentioned which he presented to the Emperor Charles V., made by Taddeo Zucarro and Battista Franca, under the direction of the brothers Flaminio and Orazzio Fontana.

Nothing was omitted which could enhance the interest and increase the excellence of those productions of artistic industry. To genius, talent, skill, and care, were united the researches of erudition, and the counsels of taste, to impart to them the greatest attainable perfection.

12. This high excellence was sustained so long as the art was protected and fostered by royal patronage. The time was not yet arrived when the patronage of the public was more advantageous than that of the sovereign; and after the decease of Guidobaldo and Orazzio Fontana, the art being left to the unaided influence of the public demand, it became necessary to meet that demand by low-priced and, therefore, inferior articles. The taste accordingly declined with the excellence which excited it, and the Italian majolica gradually but speedily lost its reputation.

About 1772, Cardinal Stoppani attempted to revive it at Urbino, and some temporary effect was produced about 1775, but it was only temporary. It is probable that the importation of Chinese porcelain into Europe, which was simultaneous with the decadence of majolica, may have had some influence in producing that result.

13. The epoch of della Robbia in Italy was followed by that of Bernard Palissy in France. This eminent potter was born at La Chapelle-Biron, a small village of the Perigord, about 1510, and died in 1589.

Although he was the author of many published works, and one upon the art which he practised with so much success, he has left no available information respecting his processes. His desire seems to have been exclusively to leave to the world a record of the unparalleled difficulties he encountered, the sacrifices he made, the sufferings he endured, and the obstinate perseverance, amounting, it must be admitted, to a sort of heroism, which he *displayed in* the attainment of his objects. In his experiments,

which were continued for a long period of time, and pursued with an admirable patience, he expended all that he was worth, even to the sale of his furniture and wardrobe.

Palissy had the weakness and ignorance so common with practical men, of inveighing against theory, yet in the only work which he has left on the subject of his art, he has not only been sparing, obscure, and mysterious in his practical details, but has mixed them up with theories of his own which only prove how much painful toil, how many abortive experiments, and how great an expenditure he would have been spared, had he condescended to consult those who were qualified to inform him of the true principles of physical and chemical sciences applicable to his researches.

14. The character of this great improver of his art was strongly marked, not only by patience, perseverance and sagacity, in the pursuit of his purposes, but by eminently high moral firmness, and unshaken rectitude. No example can be found of one to whom the well-known lines of the Roman poet are more truly applicable:

> "Justum ac tenacem propositi virum,
> Non civium ardor prava jubentium,
> Non vultus instantis tyranni
> Mente quatit solida."—Horace.

> "The man, in conscious virtue bold,
> Who dares his secret purpose hold,
> Unshaken hears the crowd's tumultuous cries,
> And th' impetuous tyrant's angry brow defies."
> Francis.

15. Palissy was a conscientious Protestant, and did not hesitate publicly to avow and express his opinions even in his discourses on subjects of his art. By this boldness and indiscretion, he was in his ninetieth year dragged before the ecclesiastical authorities, and refusing peremptorily to renounce his opinions, or to retract his expressions, he was thrown into the Bastille. He was visited there by the King, Henry III., who wished to liberate him, when the following memorable colloquy took place between the monarch and the manufacturer:

"My good man," said the king, "if you cannot conform yourself on the matter of religion, I shall be compelled to leave you in the hands of my enemies."—"Sire," replied the old man, "I was already willing to surrender my life, and could any regret have accompanied the action, it must assuredly have vanished upon hearing the great King of France say 'I am compelled.' This, sire, is a condition to which those who force *you* to act contrary to your own good disposition can never reduce *me;*

because I am prepared for death, and because your whole people have not the power to compel a simple potter to bend his knee before images which he has made."

Palissy, to the eternal disgrace of the monarch and the priests, was detained in the Bastille, where he died at little short of a hundred.

16. The works of Palissy are characterised by a peculiar style and qualities. While the forms are in general correct and pure, there is no painting properly so called. The figures are given in coloured relief, whether they be mere ornaments, representations of natural objects, or historical, mythological, or allegorical subjects. The enamel is hard and brilliant, but often disfigured by a multitude of small inequalities; a defect which is also observable in the productions of the German potters of that day. The colours are generally brilliant, but little varied. The white is yellowish, and very inferior to that of della Robbia. The other tints are confined to a pure yellow, an ochre yellow, a fine indigo blue, a greyish blue, an emerald green, a yellowish green, the violet produced by manganese, and a brownish violet. They included no fine white, nor any tint of red.

The bottoms of the articles are generally marbled with tints of blue, yellow, and brownish violet.

In fig. 23 is represented a porcelain flask (Bouteille de Chasse), attributed to this potter, preserved in the *Cabinet Sauvageot*. It is oval in form, the largest diameter being 10¼ inches, and bears the Montmorenci arms. Palissy was employed by the Duc de Montmorenci to decorate the Château d' Ecouen.

The natural objects represented on the pieces of Palissy, are remarkable for truth of form and colour, having been, with the exception of certain leaves, moulded from nature. It would appear from the selection of this class of decoration that Palissy was more or less a naturalist. The shells with which he has ornamented many of his pieces are all tertiary fossil shells from the Paris basin, and probably also that of Grignon and its environs. The fishes are those of the Seine, and the reptiles, a prevailing subject, those of the banks of the same river.

Most of the pieces, and especially the dishes and plateaux, are surcharged with objects in coloured relief, and evidently were never designed for the table, but were used to furnish the great buffets and sideboards called DRESSERS, which were placed in the dining halls of that day.

The productions of this potter must have been extremely numerous, for they are still found in great quantities in the cabinets and collections, public and private, and with the vendors of antiquities and curiosities of all countries. The varieties of

Fig. 23.

form and design, however, bore no proportion to the number of articles produced, and we accordingly find a limited number of forms and patterns, indefinitely repeated in the extant collections.

17. An oval plateau highly decorated in relief by this potter is represented in fig. 24. This piece is well known to amateurs under the name of the dish of the fair garden-girl, *plat de la Belle Jardinière*. The decorations, coloured yellow and green, are in low relief. The bottom is scaled green and reddish yellow. This piece is in the collection Sauvageot.

18. Between the middle of the seventeenth century and its close commenced the manufacture of the fine earthenware, which, without attaining the excellence of porcelain, constituted a great improvement on the previous products of this industry. This was owing partly to the discovery of a white plastic clay as a substitute for the reddish clay previously used in France, Germany, and Italy, which rendered it possible to use a colourless transparent glaze instead of the opaque coloured glaze, which had been previously used. Besides this, there were numerous improvements made in the details of the manufacture by the potters who established themselves in Staffordshire, and gave celebrity to the extensive district since known as the Potteries.

The establishment of this industry in Staffordshire originated from the circumstance of strata of good plastic clay being found

Fig. 24.

there in immediate juxta-position with the coal necessary for its conversion into the fabricated article.

The chief town of the district, Burslem, is supposed to derive its name from two Saxon words, BURN or BYRN, a *stream* or a *farm*, and LŒM, *clay*. If this be the origin of the name, it would follow that the fabrication of earthenware in that district must have prevailed since a very remote epoch.

19. About 1680, Messrs. Palmer and Bagnall, potters at Burslem, discovered accidentally the property of marine salt, by which it supplied a glaze. In some culinary process, salt being thrown into the fire its vapour came in contact with the biscuit of an unglazed article, and was observed to have the effect of giving it a glaze. The expedient was tried in the manufacture, and succeeded. The salt, when vaporised, coming in contact with the unglazed ware, was decomposed by the silica which formed so large an ingredient of the paste, and the soda deposited combining with the silica produced the glaze.

It was about this time that the brothers Elers of Nuremberg immigrated to England, and erected a small factory in Staffordshire. There were then no more than twenty-two ovens at Burslem.

20. The Messrs. Elers had not long been there before they discovered in the neighbourhood a bed of clay of very superior quality, and, erecting upon the spot itself a factory, resorted to

extraordinary and curious measures to keep in profound secrecy their materials and their processes. With this view they not only excluded most rigorously from their works all visitors whatever, but selected for their operatives the most stupid and ignorant persons they could find, and so divided the labour that no one individual possessed more knowledge than that of the very process at which he was employed. These precautions were, however, of little avail. The stimulus of profit and the spirit of enterprise are not to be repressed by such shallow expedients. A workman named Twyford imposed upon them by affecting indifference to the art, and managed to get admitted to their employment. He soon ascertained some of their secrets, but it remained for another more astute and persevering person to discover all the details of their processes. An individual named Astbury, appreciating the importance of the manufacture, and foreseeing the profits likely to arise from it, decided on adopting a course and persevering in it, which, as he imagined, and as proved by the event, would lead to a complete discovery. He affected the manners of an idiot, deceived them, and got into their employment, and was adroit enough to sustain the deception for several years, until he became complete master of their secrets. After this, the Messrs. Elers left Staffordshire in apparent disgust, and settled in London, where, at a later period, they were probably instrumental in establishing the well-known porcelain works at Chelsea.

21. One of the ingredients of fine pottery is silica, or the earth of flints. The circumstance which led to the application of this substance to the art is thus related:—Mr. Astbury, the son and successor of him who gained the knowledge of the Elers's secret by feigning idiocy, being on his road to London, and making the journey on horseback, was stopped at Dunstable in consequence of his horse being attacked with a malady of the eyes. The innkeeper at whose house he put up advised him to apply a poultice of calcined flints. Astbury observed that the flints, which before calcination were black, and semi-transparent, were by this process of calcination converted into a white opaque substance. It occurred to him that he might by like means bleach the clay of which the pottery was made, and which was reddish in its colour, by mixing with it more or less of the matter thus whitened in the fire. He accordingly realised this idea with complete success, and silica or the earth of flints became thenceforward a necessary ingredient of the paste.

22. Among the improvers and inventors of this epoch the most memorable was Josiah Wedgwood, whose name has since become so inseparably connected with this branch of the national industry.

This celebrated potter, born at Burslem in 1730, was the son of Thomas Wedgwood, who followed the same business. The education of Josiah must necessarily have been limited to reading and writing, for at the early age of eleven years he worked at the wheel in his father's pottery.

After being united in partnership for short intervals with Messrs. Harrison and Whieldon, he commenced working on his own account in a little thatched building, in 1760. He soon extended his works, erecting another small manufactory called the "Bell Works," from the fact, then unusual, that the workmen were assembled and dismissed by a bell. It was here that he commenced the fabrication of the cream-coloured ware, with a plombiferous glaze, which afterwards became so celebrated, and which being approved and patronised by Queen Charlotte, consort of George III., was called *Queen's ware*, and procured for Wedgwood the appointment of potter to the Queen.

Wedgwood was esteemed as much for his public spirit and private virtues as for his industrial enterprise and skill. It was to him was chiefly due the construction of the canal connecting the Trent with the Mersey, commenced in 1760, and completed in 1777.

His fortune being increased by inheritance as well as by his commercial success, he purchased the estate called Ridge House, where he established, in 1770, his manufactory of black ware.

It was here also that he erected the noble mansion which became his family residence, and the surrounding village called Etruria, where he established his principal works, having removed from Burslem in 1771, and where he accumulated that princely fortune, which he devoted to so many noble and charitable uses. The name conferred on this establishment, and the industrial village created around it, was taken from that of one of the ancient Italian states, which had attained a high celebrity for the tasteful forms of its potteries.

He died at Etruria, in 1795, at the age of 64.

The effects of the genius and perseverance of this prince of manufacturers were not limited to the improvement of the mere processes of fabrication. His efforts were directed with not less success and effect to the improvement of forms and decoration. He resolutely rejected the uncouth and distorted shapes which had till then prevailed, and replaced them by forms at once pure, simple and elegant. He availed himself of the collection of ancient vases, which Hamilton had brought from Italy, and took his models from them. He substituted for the vulgar style of ament which had been till then exclusively adopted, decora-arised by a severe taste, and, like the earlier potters

of Tuscany, he called to his aid the greatest living artists, procuring designs from the celebrated Flaxman, according to which he fabricated his improved wares. This system has been continued by his son and successor.

Wedgwood was as remarkable for enlightened liberality in his private character as for well-directed enterprise as a manufacturer. An example of his munificence was lately mentioned in one of the leading journals, which we cannot pass without mention here. The family attracted around them men of genius in literature and art, among whom were Sir James Mackintosh, his brother-in-law, Mr. Stuart, then editor of the *Morning Post*, Coleridge, Southey, and others. In the beginning of 1798, Coleridge received an invitation to accept the functions of minister to the Unitarian congregation at Shrewsbury. Thomas Wedgwood hearing of this wrote to him to dissuade him from taking such a step, considering it to be adverse to the prosecution of literary works, in which he was likely to found a great reputation, and to confer a great benefit on society; and that no immediate pecuniary exigency should force him to accept the proposition he enclosed a cheque for an hundred pounds. Coleridge, however, considering that the Shrewsbury appointment opened to him for the first time in his life the prospect of a certain income and permanent establishment, decided to accept it, and returned the cheque. He accordingly went to Shrewsbury, preached his probation sermon with general satisfaction to his flock, the afterwards celebrated William Hazlitt being one of his auditors. The Wedgwoods, however, sensible that the poet was misplaced, and would be lost to the world, again wrote to him, expressing that opinion, and proposed that he should at once relinquish his clerical charge, to which he was unsuited, and with princely munificence offered to place him at ease for the future by settling on him a life annuity of an hundred and fifty pounds. The offer was promptly and gratefully accepted.*

Before the commencement of Wedgwood's labours the English potteries produced wares flimsy in their materials, grotesque in their forms, and utterly destitute of all correct taste in their ornamentation, being miserable copies of the Chinese procelain. Owing to the influence of the enterprise and genius of this eminent man, the style and character of the ceramic manufacture of the country was thoroughly reformed, so that not only have the productions of Staffordshire, Derbyshire, Worcestershire, London, and other places where this industry has been established, superseded foreign goods in the home market, but they have spread over

* Edinburgh Review, April 1848, p. 379.

the whole civilised world. M. Faujas de St. Fond, a foreign writer on this subject, says :—

"The excellent workmanship of English porcelain, its solidity, the advantage which it possesses of sustaining the action of fire, its fine glaze, impenetrable to acids, the beauty and convenience of its form, and the cheapness of its price, have given rise to a commerce so active and universal, that in travelling from Paris to St. Petersburgh, from Amsterdam to the furthest part of Sweden, or from Dunkirk to the extremity of the south of France, one is served at every inn upon English ware. Spain, Portugal, and Italy are supplied with it, and vessels are loaded with it for both the Indies and the continent of America."

Fig. 28.—TURNER OR THROWER'S SHOP IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER III.

1. Improvements effected by Wedgwood.—2. General commercial advantages attending the manufacture.—3. History of Chinese porcelain. —4. Its first importation into Europe.—5. Great plasticity of the material.—6. Perfection of its forms.—7. Pagoda of Nankin.—8. Forms of vases.—9. Figure called "pou-sa."—10. Discovery of the material of porcelain in Europe.—11. Origin and history of Böttger.—12. His labours in Saxony.—13. Anecdotes of his imprisonment.—14. Is established at Dresden.—15. First results of his labours.—16. White earth of Schnorr.—17. Discovery of Saxon kaolin.—18. Establishment of the royal manufactory at Meissen.—19. Curious precautions to ensure secresy. — 20. Anecdote of Brongniart.—21. Death of Böttger.—22. Analysis of the Dresden paste.—23. Style of the Dresden porcelain.—24. Grotesque figures. 25. Secrets transpire.—26. Ringler at Hochst.—27. Paul Becker.—28. Establishment of the Royal Bavarian manufactory.—29. In other German states.—30. Invention of the Sèvres *pâte tendre*.—31. Its defects.

1. AMONG the principal improvements for which the art is indebted to the genius of Wedgwood, may be mentioned—besides

the queen's ware—a terra cotta resembling porphyry, granite, Egyptian pebble, and other ornamental stones; a black unglazed ware called basaltes, hard enough to emit sparks when struck with steel, and capable of receiving a high polish, of resisting acids, and of sustaining a high temperature; a white unglazed ware having like properties; a bamboo or cane-coloured ware of the same kind; a biscuit adapted to chemical purposes by reason of its hardness, its resistance to acids, its impenetrability by liquids; its incorrosiveness, and its refractory quality when exposed to high temperatures; and, in fine, for a production denominated JASPER, consisting of a white porcelainous biscuit of extreme beauty, having besides the properties of the basaltes above-mentioned, the quality of receiving from the application of metallic oxides colours which penetrate its entire thickness like those imparted to glass or enamel in fusion. This peculiar property, possessed by no other porcelain or earthenware body ancient or modern, renders it applicable to the production of cameos and all subjects which require to be shown in relief upon a ground of another and darker colour, the figures in relief formed with this biscuit being of the purest white.

2. We cannot give a more clear idea of the benefits conferred by this manufacture on our national industry than may be obtained from the following evidence, given by Wedgwood before a Parliamentary committee:—

"Though the manufacturing part alone in the Potteries, and their immediate vicinity, gives bread to 15 or 20,000 people, yet this is but a small object when compared with the many others which depend on it; namely, 1st, The immense quantity of inland carriage it creates throughout the kingdom, both for its raw materials and finished goods. 2nd, The great number of people employed in the extensive collieries for its use. 3rd, The still greater number employed in raising and preparing its raw materials in several distant parts of England, from near the Land's End, in Cornwall—one way along different parts of the coast, to Falmouth, Teignmouth, Exeter, Pool, Gravesend, and the Norfolk coast; the other way to Biddeford, Wales, and the Irish coast. 4th, The coasting vessels, which, after having been employed at the proper season in the Newfoundland fishery, carry these materials coastwise to Liverpool and Hull, to the amount of more than 20,000 tons yearly; and at times when, without this employment, they would be laid up idle in harbour. 5th, The further conveyance of these materials from those ports, by river and canal navigation, to the Potteries, situated in one of the most inland parts of this kingdom; and, 6th, The re-conveyance of the finished goods to the different parts of this island, where they are shipped

for every foreign market that is open to the earthenwares of England."

Mr. Wedgwood very justly observed further, that this manufacture is attended with some circumstances of advantage which are almost peculiar to itself; viz. that the value of the finished goods consists almost wholly in the labour bestowed upon them; that every ton of raw materials produces several tons of merchandise for shipping, the freight being paid, not upon the weight, but according to the bulk; that scarcely a vessel leaves any of our ports whose lading is not in part made up of these cheap, bulky, and, for these reasons, valuable articles, to this maritime country; and that fully five parts in six of the aggregate manufactures of the Potteries are exported to foreign markets.

3. While the potters of Europe were engaged with more or less success in the fabrication of an earthenware, which, whatever may have been its merits, was formed of a paste coarse and opaque; the fine porcelain, which attracted so much and so well merited admiration, was for a long period of time obtained exclusively from the East.

Without insisting on the claims of the Chinese to the production of this beautiful article at the epochs of remote antiquity, which have been already referred to, there is sufficiently conclusive evidence that they possessed and practised the art hundreds of years before it was discovered in Europe or elsewhere. Thus it is certain that fine porcelain was made in China 163 B.C., and that its fabrication existed still in 442, A.D.

The first porcelain oven, however, of which there are distinct and detailed historic records in China was called TAOU-YAOU, and was situate at Chang-Nan in the province of KEANG-SI. Tributes of porcelain were sent from this factory to the court of Woo-tih in the year 630 A.D.*

The celebrated works of King-Te-Tching, already mentioned, were not established until 1000 A.D.

In the Ceramic Museum of Dresden are pieces of porcelain which bear dates from 1403 to 1425, from 1465 to 1488, and 1573 to 1620, which are, therefore, spread over two centuries. The stationary character of the Chinese is remarkably indicated by the fact that the earliest of these specimens does not differ in the slightest degree from the latest, either in its mode of fabrication, the nature of its material, nor even in its colours or style of decoration.

4. It was not until 1518 that the Chinese porcelain was brought to Europe by the Portuguese, and two centuries elapsed before any successful attempt was made to fabricate it. In England this fine

* Morrison's Chinese Dictionary, part iii., p. 326, word "porcelain."

pottery was called CHINA, from the place of its production, but on the Continent it was distinguished from the coarser sorts of pottery by the name porcelain; the origin of which is not certain, but which is supposed to be derived from the Portuguese word PORCELLANA (a drinking cup).

Although the art of fabricating porcelain was thus late in reaching Europe, it extended from China to other adjacent parts of Asia, and especially to Japan, and even to Persia, at a much earlier period.

5. The paste of which the oriental porcelain is composed is generally deficient in pure whiteness, having rather a grayish hue, while the glaze which covers it is greenish. It is hard, brittle, and stands the fire only with many precautions. It is not as translucent as the fine porcelain manufactured in France and Germany.

That in its unbaked state it possesses the quality of plasticity in an extraordinary degree is rendered manifest by various circumstances. The process of the fabrication is one to which no material but the most plastic could lend itself. It is also proved by the enormous magnitude of the vases which are fabricated in a single piece, free from those defects which would be inevitable with a material not possessing that quality in the highest degree.

Without being as fusible as the paste of which the tender porcelain is formed, it is less infusible than that of the hard European porcelain. A cup of Chinese porcelain was softened and distorted in one of the Sèvres ovens.

6. The forms given to the Chinese porcelain are remarkable for their perfection, even in the case of articles presenting the greatest difficulties and delicacies. The pieces, although large, are frequently not thicker than an egg shell. Open cylindrical vases eight or nine inches in height are proportionally delicate; plates decorated with ornaments in relief, are remarkable for their lightness and evenness of surface; and as to magnitude, the vases made in a single piece are sometimes fifty-four inches high and twenty-two inches diameter. A vase of these dimensions is in the possession of M. Cambacères, remarkable for the magnificence of its ornamentation in relief, and its dragon-formed handles.

7. Among the pieces of Chinese porcelain most memorable for magnitude, is the celebrated pagoda of Nankin in the province of Kiang-Ming, the height of which is 213 feet. This structure consists of nine stages, the walls of each of which are covered with plates of coarse porcelain. Two models of this, on a small scale, may be seen in the Imperial (Royal) Library at Paris.

8. One of the most characteristic forms of the Chinese vases is

that of the two round vases or bottles connected by a contracted neck, of which figs. 25 and 26 are examples. The most usual ornaments on these vases are lizards or other reptiles with a

Fig. 25.

Fig. 26.

curved and bifurcated tail, which are represented crawling from one of the vases to the other in the contracted neck, by which they are connected.

This form of vase has been seen no where on the old continent

Fig. 27.

except in China and in Egypt. M. Brongniart, however, notices

a fact which has some interest for geographers and antiquaries. It is that vases of the same form and similar decoration have been found among the remains of ancient pottery in Peru and Chili in South America, which must have existed ages before the time of Columbus. One of these jars, found in Peru, is represented in fig. 27. It will be observed as a coincidence deserving of notice, that while in the Chinese vases lizards are represented creeping from one part of the vase to the other, a species of small ape is represented in a like position and action on the Peruvian vase, and that in both cases the tails are bifurcated.

9. The figures so often seen on Chinese porcelain, with a large paunch, which amateurs call POU-SA, and which are often in coloured glaze, represent the Chinese god of porcelain, whom a legend records as being a martyr to the art. Being engaged in the process of baking, he found that the action of the furnace was irregular, and such as must destroy the articles in the oven. To prevent this, according to the Chinese traditions, he sacrificed himself by throwing himself bodily into the furnace, and attained his object.

10. It was not until the beginning of the last century that the art of fabricating the true porcelain made its way to Europe. The circumstances attending its discovery are highly interesting and curious.

During the seventeenth century, the oriental porcelain which had been brought to Europe by the Portuguese, and which was distinguished from the wares fabricated there by the name of porcelain, excited the unbounded admiration of all classes. No efforts were left untried to discover its materials and the means of producing it. European agents in the East, and more particularly Father Entrecolles already mentioned, contrived, in spite of the jealous vigilance of the Chinese, to obtain specimens of the materials of which the precious ware was fabricated. But these materials were in the state in which they were prepared for the potter, and not in the raw form in which they were first taken from the quarries. Nevertheless, they were assiduously examined and analysed by the most eminent chemists and physicists of the day.

These researches, however, led to no practical result; and, as so often happens in the progress of discovery, as well in the arts as in the sciences, chance accomplished what sagacity and industry failed to attain. Even chance, however, can accomplish nothing, unless it presents its results where talent and genius are present to recognise them and turn them to account. Happily, in the present case, the talent and genius were not wanting. Saxony was destined to have the honour of the first accomplishment of this it advance in the ornamental arts.

11. John Frederick Böttger (or Böttcher) was born at Schlaiz, in Voigtland, on the 4th of February, 1682. He was brought up at Magdeburg, where his father had a place in the Mint. The father was given to alchemy, and pretended to the discovery of the philosopher's stone, the secret of which he was reputed to have imparted to his son. In the superstitious spirit of the age, Böttger believed himself gifted with the power of divining the future, in consequence of being a "Sabbath child," having chanced to come into the world on a Sunday.

He was apprenticed to an apothecary named Zorn, at Berlin, but the fascinations of alchemy did not long permit him to give his attention to the preparation of medicines; and he deserted his master and his business. He was soon, however, obliged to return, and was received and forgiven, on the condition of abandoning his favourite study of alchemy.

Soon after this, being informed that the fame of his researches and the rumours of his prospects of successful results, which gave him among his fellow citizens the name of the "Goldmaker," had reached the ears of Frederick I. of Prussia, and fearing, or affecting to fear, that he would be seized by royal order for the purpose of extorting his secret from him, he again fled, and took refuge in Saxony, where his arrest was procured by the Prussian authorities. The Elector of Saxony, however, having resolved not to surrender so precious a personage, had him carried away from Wittemberg, and secretly confined, but well cared for and treated.

He was supplied with all the means necessary to carry on his chemical researches, but was kept under constant surveillance, and was in reality a prisoner.

12. After some time the Elector, finding that the labours and researches of Böttger were without any practical results, and suspecting all the prospects of success so much vaunted to be mere illusions, but finding nevertheless that his protegé and prisoner was endowed with considerable natural genius, combined with much acquaintance with chemical science, such as it was at that time, resolved on endeavouring to turn Böttger to better account; and, with this view, put him in communication with EHRENFRIED WALTHER DE TSCHIRNHAUSEN, who was then occupied in experimental researches directed to the improvement of the fabrication of earthenware, and more especially to the discovery of means for the production of the oriental porcelain.

Böttger himself, having probably some misgivings as to his eventual success in the fabrication of gold, was the more ready to give ear to the counsels and suggestions of Tschirnhausen, and was soon brought to cooperate with that person, and to deliver

himself with all his characteristic ardour to a series of experiments on the fabrication of an improved pottery.

13. In order to remove them more effectually from popular interference and observation, the Elector had established Böttger and Tschirnhausen in the château of Albrechtsburg at Meissen. They were there abundantly supplied with artisans to work under them, and with all that was necessary for a porcelain laboratory and workshop. Böttger was liberally afforded all that could render life agreeable, except liberty. A carriage was provided for him, and he was allowed to visit Dresden and the neighbourhood at his pleasure, but an officer always accompanied him, never for a moment losing sight of him, lest he should escape, carrying with him his inestimable secrets.

The first result of their labours, which were still prosecuted under the strict surveillance of government, was merely the production of articles of earthenware, composed of a red and compact paste, differing, however, in nothing which was essential from the pottery of Spain, Italy, and France.

In 1706, the King of Sweden, Charles XII., entering Saxony, the King of Poland, Elector of Saxony, fearing that Böttger should be seized and carried away with his secrets, had him conducted with Tschirnhausen and three principal artisans, Ritter, Romanns, and Beichling, to the fortress of Konigstein, where they were strictly imprisoned, but supplied with a laboratory, where they were allowed to prosecute ther labours under rigid surveillance. Böttger is related to have lost none of his gaiety and animal spirits here. He amused his leisure hours and those of his companions in captivity in various ways, and among others, by the composition and recitation of verses.

Notwithstanding all the precautions which were observed for their safe keeping, Ritter and the others managed to form a plan of escape.

14. In 1707, after remaining a year at Konigstein, Böttger and Tschirnhausen were reconducted to Dresden, and established in a new laboratory which had been prepared for them on the Jungferbastei. Here they continued to prosecute their labours, all their researches being directed still to the discovery of the means of producing a pottery such as that which came from China. Their labours were incessant, and their spirit indefatigable; and it is related as an example of the untiring spirit of Böttger, that when it was considered necessary to watch the oven day and night for three or four successive days, he never left them himself, and kept his assistants awake by his inexhaustible fund of anecdote, and the gay and frequent sallies of his conversation.

It was said, that at this time some of the firing processes which

required a more intense heat than could be obtained by the furnaces then in use, were effected by means of the solar rays collected in the focus of a large burning mirror, constructed by Tschirnhausen.

Tschirnhausen died the next year, 1708. This event, however, did not interrupt the course of experiments. Large ovens were erected, and batches of earthenware were exposed in them to the effect of the furnaces, often for five consecutive days and nights, producing successful results so far as the nature of the clays used permitted. The king, wishing to witness one of these experiments, they drew from the oven, in his presence, a tea-pot, still red-hot, which, being plunged in water, sustained the sudden change of temperature without injury.

15. The pottery thus produced was still, however, only a good stone-ware, with a red body, to which the brilliancy of porcelain was attempted to be imparted, either by polishing it on the wheel of a lapidary, or by covering it with an opaque-coloured glaze, which was vitrified at a comparatively low temperature.

At length, however, chance brought to Böttger a knowledge of the constituents of the true oriental porcelain, so long and so vainly sought for.

16. About this time, John Schnorr, one of the most wealthy and extensive iron-masters of Erzgebirge, happened to pass on horseback near Aue, where he observed the action of his horse to be impeded by reason of his feet sticking in a sort of white, soft, and tenacious earth, which lay upon the road, and which evidently formed the superficial stratum of the ground at that place. At that time, the use of hair-powder was universal, and that article formed consequently an object of commerce of capital importance. Engaged largely himself in commercial speculations, and endowed with an enterprising genius and quick sagacity, Schnorr conceived the idea of submitting this white clay to experiment, for the purpose of purifying it, and reducing it to a fine powder, which might find a profitable market as hair-powder, thus displacing the powder produced from wheaten flour.

Schnorr realised this project with complete success, and after a series of experiments made at Carlsfeld, established a manufactory of it, and soon found an extensive market and large demand for the article at Dresden, Leipsic, Zittau, and, in short, in all the German towns, where the new powder was known under the name of Schnorr's White Earth.

17. Böttger, like all others of that day, wearing powder, he happened, while Klunker, his valet, was occupied in dressing his hair, to take in his hand a packet of the powder which he was using, and being struck with its extraordinary weight, greatly

exceeding that of powder made from flour, he asked Klunker where he bought it, and what it was called. Being informed that it was "Schnorr's White Earth," the idea instantly occurred to him that a clay so beautifully white, and admitting of pulverisation so infinitely fine, would serve as a material for fabricating an improved pottery; he instantly ordered a quantity of it to be procured sufficient for an experiment, which was no sooner tried than its precious qualities became conspicuously apparent. It was, in fact, the true kaolin, the very material of which the so highly-prized oriental porcelain was formed, and for which so many and such fruitless searches had been made in all parts of Europe.

18. The king now proceeded to establish the Royal Manufactory of Porcelain, which has since attained such universal celebrity. The Château of Albrechtsburg, at Meissen, was assigned to it, and Böttger was appointed its director.

The most rigid precautions were adopted to prevent the discovery, or its consequences, passing out of the country. The exportation of the "white earth" was interdicted under the most severe penalties, and it was transported from Aue to the manufactory at Meissen in sealed barrels, under military escort, and in the care of sworn keepers.

The precautions to ensure the secresy of the processes exceeded all belief. The precept solemnly inculcated into all who were employed in the manufactory, from the director to the lowest labourer, was "SECRESY TILL DEATH!" An oath to this effect was solemnly administered monthly to all the foremen and principal artisans, and was painted in conspicuous characters on the doors of all the workshops.

Whoever should be detected in disclosing any of the secrets of the processes was menaced by the royal ordinances with imprisonment for life in the fortress of Königstein.

19. In a word, the royal manufactory of Meissen was placed under the rigorous conditions of a fortress, the drawbridge never being lowered except at night. No one was admitted within its walls except those employed in the works; and even when the king brought foreigners of distinction to view the works, the processes were carefully concealed from them.

20. So late as the year 1812, M. Brongniart, then director of the Royal Manufactory of Sèvres, was sent by the Emperor Napoleon to inspect the porcelain works of Germany, and among others he visited those of Meissen. Even then the same rigorous system of secresy and exclusion was maintained. The King of Saxony, at the personal request of Napoleon, permitted M. Brongniart to see the works; but in order to do so, he was obliged to absolve M. Kuhn, the director, from his oath of exclusion. He did so,

as far as related to M. Brongniart individually, but he refused to include in the admission the associate who accompanied him.

The fine hard porcelain was now manufactured at Meissen, the colours, forms, painting and gilding of the oriental porcelain being so perfectly re-produced, that on examining the specimens of this early date preserved in the Dresden collection, M. Brongniart affirmed that he was only able to ascertain that they were not genuine Chinese porcelain by the mark of the Meissen manufactory impressed on them.

21. Böttger was unable to bear his elevation. Intoxicated with success, and supplied with pecuniary resources beyond his habits, he fell into a course of dissipation, and died in 1719, at the early age of thirty-five.

Such was the origin of the manufactory of porcelain at Dresden, which has since obtained a world-wide celebrity, and the source from which Europe for more than a hundred years obtained the most admired productions of the ceramic art.

22. The kaolin of Aue, discovered by the accidental circumstances above stated, continued, and still continues, to be used as one of the materials of the Saxon porcelain. Two sorts of paste are at present used in this manufacture. What is called the service paste, or that used for porcelain in general, is thus composed:

Kaolin of Aue	18
Kaolin of Sosa	18
Kaolin of Seidlitz	36
Feldspar, &c.	8
	100

For the statuary porcelain the feldspar of Carlsbad and quartz are mixed with the kaolin of Aue.

The manufacture of fine porcelain being thus established in Saxony, it soon spread to other parts of Europe, partly by the treachery and desertion of the parties engaged in the Meissen manufactory, and partly by the invention of other materials for the paste; and, in fine, by the discovery of strata of kaolin in other localities.

23. The style of the Dresden porcelain is familiar to all amateurs, and, whatever difference of opinion may prevail as to its taste, there can be none as to the admirable excellence of its execution. All who have visited the collection at Dresden, will be familiar with the series of animals, represented on a scale approaching to the natural size, including bears, rhinoceroses, vultures, peacocks, &c., made for the grand staircase which conducts to the electoral library. These were fabricated as early as 1730. At a later

period, when the manufacture had undergone improvements, large ornamental pieces of porcelain were made, such as the slabs of consoles and tables, some of which measure from 45 to 50 inches by 25, and are richly decorated with flowers.

24. Among the varieties of Dresden porcelain the grotesque figures and groups have always been much admired for their execution, if not for their style. The costumes are especially admirable, and the representation of fine work, such as lace, truly wonderful. One of the grotesque pieces which has attained most celebrity, and is familiar to all amateurs, is the famous tailor of the Count de Bruhl, a figure which is remarkable for the difficulty of its execution owing to the numerous accessories which it includes. The figure of the tailor is represented riding on a goat surrounded with all the implements and appendages of his trade, and is about 20 inches in height. This celebrated group was composed by Kundler in 1760, and is usually sold for about 12*l.*

The Dresden manufacture has always been remarkable for its representation of flowers; and a beautiful specimen of this work was seen in the Great Exhibition in 1851, consisting of a *camellia japonica* with leaves and white flowers in porcelain, in a gilt pot, on a stand of white and gold porcelain. This article is priced at 90*l.*

25. The efforts made to conceal the important discovery thus made, and to monopolise the manufacture of fine porcelain at Dresden, were ineffectual. The force of interest proved more powerful than the respect for oaths, and the art, as improved in Saxony, soon spread to other parts of Germany.

One of the foremen of Meissen, named Stobzel, had deserted from that establishment about the year 1718, and escaped to Vienna, where, aided by a Belgian named Pasquier, and favoured by a privilege, or a sort of monopoly, for twenty-five years, granted to him by the Emperor Charles VI., he established, in 1720, a small porcelain manufactory. Not having, however, sufficient capital to carry it on, it declined, and was finally purchased by the Empress Maria Theresa in 1744, and erected into a royal manufactory. During nearly twenty years it required considerable subsidies for its support, but at length, by good management, it became profitable in 1760, and in 1780 yielded an annual profit of about 4000*l.* The number of operatives who were lately employed in this factory was about 400. The kaolin or porcelain clay used in this factory, until 1812, was obtained from the neighbourhood of Passau, on the confines of Bavaria, and from Prinzdorf, in Hungary. Lately, however, it has been supplied by clay obtained from the neighbourhood of Brün, in Moravia, and *Unghbar*, in Hungary.

As deserters from Meissen were instrumental in establishing the manufactory of porcelain at Vienna, deserters from Vienna soon spread the knowledge of the art to a greater or less extent in other parts of Germany.

26. Ringler, one of those who had originally deserted from Meissen, again breaking his engagements, and disregarding his oaths, left Vienna, taking with him plans of the ovens, and associating himself with M. Gelz, a manufacturer of earthenware at Höchst, near Francfort-on-the-Maine, he enabled that potter, with the aid of Lowenfink and Bengraf, two others, to establish the manufacture of the fine porcelain.

The German princes, captivated by the productions of this art, and ambitious, each in his own state, to establish a royal manufactory, in imitation of those of Dresden and Vienna, left no means of corruption and seduction untried to attract the potters, or even the subordinate workmen, who were engaged in the manufactories already established. Thus, the Duke of Brunswick endeavoured, by highly advantageous offers, to tempt the potter Bengraf to desert his employer, and succeeded, though not without much delay and many difficulties, for Bengraf was arrested by order of the Elector of Mentz, and was kept without food, until he was compelled to leave with his employer the full details of his processes, and to verify their exactitude. At length he was permitted to depart, and, in fine, he founded, in 1750, the well-known manufactory of Furstenberg, on the Weser. But as he died before his processes were carried into practical effect, the Duke of Brunswick failed in his object, and lost the expense he had incurred. He resorted in vain to the aid of an eminent chemist of that day, the Baron de Lang, to find means of realising the plans of Bengraf.

Ringler having remained at Höchst, continued to direct the processes of that manufactory, taking care, however, to conceal his processes, so that without his personal superintendence the works could not proceed. Being addicted to drinking, his companions, availing themselves of his infirmity, and knowing that he usually carried on his person receipts for his processes, tempted him into an excessive indulgence in wine, which ended in his falling into a state of insensibility. Availing themselves of this, they rifled him of his papers, and his receipts being copied and re-copied, were carried about the German States, and sold for considerable sums to wealthy persons, who considered themselves fortunate in becoming the possessors of the processes of an art so much and so universally admired.

27. Among these hawkers of Ringler's receipts or notes, one of the most noted and active was a certain Paul Becker, who, after

travelling through France and the Netherlands, at length settled in Brunswick, where he received a pension from the Duke, on the condition of ceasing from his peregrinations. Most of the notes and receipts which were thus put in circulation, were either garbled and fragmentary, or altogether spurious, so that little or no practical advantage was derived by those who became their possessors.

Ringler quitting Höchst, went to Frankenthal, where, associating himself with a merchant, named Hammung, he established a porcelain factory, which afterwards became one of the best known in Germany.

28. He went to Munich, where he established, under the protection of the King of Bavaria, the royal porcelain works at Nymphenburg, within a few miles of the city, in 1758.

This establishment still continues, and is now the Royal porcelain manufactory of Bavaria. The white biscuit is manufactured at Nymphenburg, and its ornamentation effected in workshops at Munich. The porcelain clay used in this manufactory is obtained near Passau, already mentioned, the felspar from Raberstein, in Bavaria, and the quartz from Abensburg, near Ratisbon. It was, in like manner, by means of information brought by deserters and runaways from factory to factory, that the fabrication of porcelain came to be established successively in the royal manufactories of Louisberg near Stuttgard, at Berlin, Copenhagen, Brunswick, and St. Petersburgh.

After the peace of Hubertsburgh, Frederick II. of Prussia, erected the royal manufactory of Berlin. While he was master of Dresden, he sent a considerable quantity of the porcelain clay of Meissen, and several of the operatives of this factory, to Berlin, to aid in the establishment of the manufactory in that city.

29. Chance, which played so remarkable a part in the progress of the ceramic art elsewhere, was also the origin of its establishment in the Thuringen.

In 1758, an old woman brought to the laboratory of the chemist Macheleid, a powder, which she proposed to be used as sand for drying writing. The grain and colour of this powder struck Henry Macheleid, the son of the chemist, who had studied at Jena, as bearing a resemblance to china clay. He submitted it to analysis, and found that it was kaolin. In fine, he succeeded in making porcelain with it, and founded in 1762 a manufactory of that article at Sitzerode, which in 1767 was transferred to Volkstadt, and became the origin of all the other manufactories of that district of the German states.

While the art made this progress in Germany, the French failing to discover either a true kaolin or any other clay

having the qualities necessary to render it a tolerable substitute for the fine china clay, directed all their efforts to invent some artificial composition which might serve the purpose and enable them to compete with foreign potters.

The result was the invention of an artificial imitation of the porcelain paste, which soon became the basis of a great manufactory in France, and which continued for half a century to be known as the *pâte tendre* of the Royal manufactory of Sèvres.

This material did not contain a particle of kaolin or felspar, the essential constituents of all genuine porcelain. Its composition was subject from time to time to slight variations; for, for the best porcelain, it consisted of the following constituents in an hundred parts by weight:—

Fused nitre (mineral crystals)	22·0
Grey sea-salt	7·2
Alum	3·6
Soda of Alicant	3·6
Gypsum of Montmartre (plaster of Paris)	3·6
Sand of Fontainbleau	60·0
	100·0

These materials being well mixed, were fritted either in the porcelain oven, or in an oven expressly appropriated to this process. It was usual, however, to calcine the alum and the gypsum previously to disengaging their water of crystallisation.

The dough called the *pâte tendre*, was formed by the mixture of this frit with white chalk and calcareous marls from the gypseous earth of Argenteuil, in the following proportions by weight:—

Frit	75
Chalk	17
Gypseous earth	8
	100

The whiteness and consistency or hardness of this dough was modified by varying the proportion of chalk.

All these materials were intimately kneaded together, bruised with water in a mill, and in fine passed through silken sieves.

The glaze used for this factitious biscuit was composed as follows:—

Litharge	38
Calcined sand of Fontainbleau	27
Calcined silex	11
Sub-carbonate of potash	15
Sub-carbonate of soda	9
	100

31. This paste after all was so utterly wanting in plasticity a

consistency that it could not be worked on the potter's wheel, and was even moulded not without much difficulty.

To give it sufficient tenacity and consistency to prevent it from cracking or crumbling to pieces in the process of moulding, it was mixed with about twelve per cent. of its own weight of a mixture of black soap and parchment size, the soap at a later period being replaced by a solution of tragacanth gum, to which are attributed the saline efflorescences which were occasionally manifested on the articles fabricated. In the process of turning the moulded pieces a saline and silicious dust was produced, which was extremely injurious to the potters, and caused asthmatic and pulmonary complaints. This was one of the reasons why the fabrication of tender porcelain was the more readily discontinued after the discovery of kaolin.

Owing to the want of plasticity and coherence in this artificial paste, great difficulties were encountered in the several stages of its manufacture. The want of tenacity rendered it necessary, when the articles were placed in the oven, to support all the projecting parts during the process of baking; and, in order that the forms of these parts might not be distorted, it was necessary that their supports should be formed of the same paste as the articles themselves, so that the whole mass, including the supports, might contract together. The linear dimensions contracted in the baking by one-seventh, and, consequently, the bulk or volume of the article was diminished in the proportion of three to two.

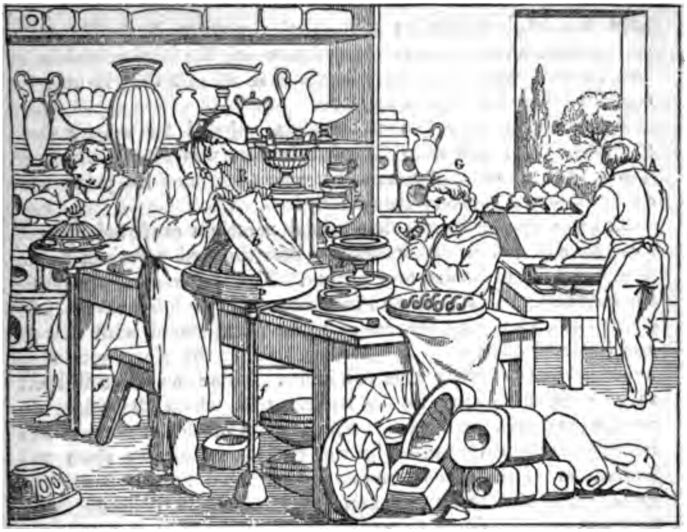


Fig. 35.—MOULDER'S SHOP IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER IV.

1. Meaning of the epithet "tender" as applied to porcelain.—2. Qualities and value of this porcelain.—3. Art of making it not lost.—4. Origin of the Sèvres manufactory.—5. Efforts to discover kaolin—Paul Hannong.—6. Kaolin of Limoges discovered.—7. Anecdote of Madame Darnet.—8. English porcelain at Bow, Derby, and Worcester.—9. Cornish china clay.—10. Properties of true porcelain.—11. Stoneware.—12. Cause of translucency.—13. Hard and tender porcelain distinguished.—14. English tender porcelain.—15. Mode of preparing the clay.—16. Statuary porcelain.—17. Process of its fabrication.—18. Process of producing colours on porcelain.—19. Coloured figures on common ware; press and bat printing.—20. Distinctive marks of the manufactories—21. Various recent applications of the art.

1. THE epithet *tender*, applied to this porcelain, must not be understood as implying the quality of softness. It is intended, on the other hand, to express two qualities by which it is distinguished

from the hard porcelain: first, that the paste is fusible at a certain temperature lower than that at which the hard porcelain is baked; and, secondly, that the glaze is so soft that it may be scratched with a steel fork or knife.

This artificial imitation of porcelain enjoyed for a long time great celebrity; and after its manufacture was discontinued, it was still more eagerly sought by amateurs, and its price was enhanced by its comparative scarcity.

2. The very defects of this artificial porcelain conferred upon it some advantages, in its decoration, over the real porcelain made from the paste of kaolin and felspar. The softness of the glaze caused painting laid over it to penetrate more or less into it, and thus to assume the appearance of being incorporated with it. It had the same effect as if it were placed under the glaze, retaining nevertheless the most perfect brilliancy. This is an effect difficult to be attained, owing to the facility with which the colouring matter is affected by the saline constituents of the glaze. It has not reappeared in the productions of the Sèvres factory since the fabrication of the *pâte tendre* was discontinued there. Since the great Exhibition, however, some of the British manufacturers have produced similar effects.

There are certain coloured grounds which are eminently characteristic of the old Sèvres porcelain, the proper porcelain paste not being in the same degree susceptible of receiving them. These are the beautiful light blue called TURQUOISE, from its resemblance to the colour of the stone of that name, the GROS BLEU, the GREEN obtained from copper, and the red distinguished as the ROSE DUBARRY, from the preference shewn to it by the notorious mistress of Louis XV.

Although this factitious ware contained no portion of either of the essential constituents of true porcelain, and ought not, therefore, ever to have received the name, or to be regarded as anything else than a spurious imitation of that admired production of Art; it must at the same time be admitted to be, in its superficial and external qualities, a beautiful copy of a beautiful original, and to require in its preparation and fabrication much more profound resources of science and art than what is composed chiefly of matters which nature presents nearly in the state in which they enter into the composition of the article fabricated. To discover and fitly combine the complicated elements of this artificial porcelain required patient research, great chemical skill, much sagacity, perseverance, and genius; while the casual discovery of a vein of kaolin and felspar would have at once enabled any potter, already master of his art, to fabricate the [illegible]uine porcelain.

The fabrication of this celebrated pottery commenced in France about the year 1695, and was continued for more than a century. The existence of true kaolin in France was not discovered until 1768, when the manufacture of real porcelain was commenced, and was prosecuted concurrently with the fictitious porcelain until 1804, when the fabrication of the latter was discontinued; and since that time the real porcelain only has been produced in the French Royal Manufactory.

3. Among amateurs in porcelain, including even those who are otherwise well-informed, there prevails a notion that the art of fabricating the tender porcelain of Sèvres has been lost, and that, since it is impossible to reproduce the articles, they must necessarily have a high value in the market. This, however, is erroneous. All the materials and processes for the fabrication of this description of artificial porcelain are preserved at Sévres, and the manufacture can be re-established whenever it is desired to do so. Indeed, we are informed that the Administration entertains an intention of recommencing the fabrication of this description of porcelain for articles of ornament, such as vases, pictures, &c., the imperfections incidental to it not affecting such objects.

In 1695, when the first attempt at the fabrication of the *pâte tendre* was made, the porcelain works at St. Cloud were the property of a private individual named Morin. The invention of this artificial paste was the result of twenty-five years of labour and research. It appears, therefore, that this manufacture commenced about fifteen years before the discovery of kaolin, and the commencement of the fabrication of hard or real porcelain at Dresden.

4. The establishment which has since attained such celebrity as the Royal Sèvres Porcelain Works, was previously established at Vincennes, where it was first conducted as a private enterprise. In 1753, Louis XV. became joint-proprietor of it, taking a third share, and gave it the sanction of royal protection, and the title of the Royal Manufacture of Porcelain. Having attained, about 1754, great celebrity from the extraordinary perfection and beauty of its productions, and especially for a magnificent service presented by the king to the Empress Catherine of Russia, the manufacture enlarging its works, the buildings at Vincennes were found to be too confined for its more extended operations: and a site having been obtained at the village of Sèvres, on the highroad from Paris to Versailles, a building on a vast scale was erected there for the manufacture, which was removed there in 1756.

A few years later, in 1760, the king purchased the interests of

the other proprietors, and the works became, and have ever since continued to be, the exclusive property of the Government.

5. It may be easily imagined that the celebrity of the German porcelain, and more especially that of Dresden, excited the most lively desire, and the most unceasing endeavours, to discover in France the precious mineral which alone formed the base of the genuine article. It was necessary, however, first to ascertain what the actual material was, which still remained to a great extent a secret; and next to discover where, if at all, it could be obtained in France.

In 1753, just before the removal of the Royal Manufactory from Vincennes to Sèvres, Paul Hannong, a citizen of Strasburg, who was proprietor of earthenware and porcelain works at Hagenau, being in possession of the full knowledge of the materials and processes of the German porcelain manufacture, proposed to M. Boileau, director of the manufactory at Vincennes, to sell to that establishment the secret of the manufacture, for which he demanded 4000*l.* in cash, and a life annuity of 480*l.* This proposal being declined, a royal decree in 1754 prohibited him from carrying on his works in France, and he accordingly established them at Frankenthal.

Paul Hannong died and was succeeded by his brother Pierre Antoine, with whom the French Government re-opened the negotiations which had been broken off by reason of the exorbitant demands of Paul. A greater facility now appearing to be manifested, the ministers of Louis XV. spared no exertion to secure to France the possession of an art so highly esteemed, and to rescue the country from the necessity of obtaining only by importation articles so highly prized. M. Boileau, the director of the royal works at Sèvres, was sent to Frankenthal with full powers, and the result of his negotiation was a contract signed on the 29th July, 1761, by which Pierre Antoine Hannong engaged to make known all the processes and the materials for manufacturing the true porcelain. Eventually, however, the execution of this contract to the advantage of the French government was rendered impossible by the fact, not foreseen, that the raw materials, kaolin and felspar, indispensable for the fabrication of the porcelain, not having been discovered in France, could only be obtained from countries where their exportation was prohibited. Under these circumstances the contract with Hannong was dissolved, the Government, however, granting him as compensation a sum of 160*l.* and a life annuity of 48*l.*

6. The time, however, had now arrived when chance was destined *to do for* the porcelain manufacture in France what it had done *elsewhere,* by leading to the discovery of kaolin.

Madame Darnet, the wife of a village surgeon, residing at St. Yrieix, near Limoges, accidentally found in a valley in the neighbourhood of that town a white unctuous earth, which she regarded as being capable of being rendered useful in the washing of linen. With this purpose she showed it to her husband, who, better informed, suspected other and more valuable properties in it, and undertook a journey to Bordeaux to submit it to a chemist of that place, named Villaris. This person, who had been already informed of the qualities necessary for porcelain clay, and of the eagerness with which it was sought for, suspected that the specimen brought to him by M. Darnet possessed these qualities. It was accordingly sent to Macquer, the chemist at Paris, who was then occupied in experiments on the improvement of porcelain. He immediately recognised in this specimen of clay the true kaolin, and went to St. Yrieix in August 1768, where he found a large vein of this precious material. Experiments were made upon it upon a considerable scale at Sèvres, where all doubts upon the subject were soon removed; and the kaolin of St. Yrieix near Limoges was immediately adopted as the material, and the fabrication of the hard porcelain was commenced.

7. M. Brongniart relates a curious and interesting anecdote connected with this subject. He says that, in 1825, being at Sèvres, where he was still director, an aged woman addressed herself to him one day supplicating temporary relief, and apparently suffering from extreme want. She asked for aid to enable her to return on foot to St. Yrieix, whence she had come. This woman was Madame Darnet, the discoverer of the kaolin of Limoges. The relief she sought was immediately given to her; and, on the application of M. Brongniart, Louis XVIII. granted her a small pension on the civil list, which she enjoyed till her death.

8. The first English porcelain was manufactured at Bow and Chelsea, near London, the paste being composed of a mixture of the sand from Alum Bay, in the Isle of Wight, with a plastic clay and powdered flint glass; this was covered with a leaden glaze. This manufactory had considerable success.

In 1748, the manufacture was transferred to Derby; and in 1751, Dr. Wale established at Worcester a manufactory of tender porcelain, called the "Worcester Porcelain Company," which still exists, though in other hands. To Dr. Wale is attributed the invention of printing on porcelain, by the transferring of printed patterns from paper to the biscuit. The proposed design is first engraved on copper, and the colouring matter being applied to the engraving in the same manner as in common copper-plate printing, the design is transferred to paper. This paper is afterwards applied to the

biscuit, to which the colouring matter forming the design adheres. The paper is then dissolved and washed off, the colouring matter forming the design remaining upon the biscuit. The biscuit is then glazed over the design with a glass glaze, so that after vitrification the design appears under the glass.

The original Worcester Porcelain Company principally limited their business to the manufacture of blue and white porcelain, in imitation of that of Nankin, and making the Japanese pottery. Cookworthy, of Plymouth, continued to carry on the porcelain business at Worcester until 1783, when the manufactory fell into the hands of Mr. Thomas Flight.

9. About 1751, Messrs. Littler, Yates, and Baddeley attempted the same manufacture in Staffordshire, but without success, and it was not until 1765 that Messrs. Baddeley and Fletcher succeeded in the manufacture of porcelain at Shelton.

The kaolin or china clay, as it is usually called, which is used in the manufacture of British porcelain, is found in the counties of Cornwall, Devon, and Dorset. That of Cornwall was discovered about the same time as that of the discovery of the kaolin of St. Yrieix, in 1768, by Cookworthy. This is the most esteemed, and its introduction into the manufacture of porcelain gave a great impulse to the art.

10. The qualities by which porcelain is distinguished from the inferior productions of the potter are, density, whiteness, transparency, and fine texture of the glaze. These properties are estimated in the order wherein they are here enumerated, compactness of body being the point which it is considered most desirable to attain. The glaze, as seen in the finished porcelain, should not put on a lustrous appearance; but while beautifully smooth to the touch, should present to the eye rather the softness of velvet than the gloss of satin. This peculiar semblance will only be produced with glaze that melts with difficulty, and when the heat has been raised precisely to, and not beyond, the point that is necessary for its fusion.

11. Stoneware is a very perfect kind of pottery, and approaches nearer than any other description to the character of porcelain. Its body is exceedingly dense and compact, so much so, indeed, that although vessels formed of it are usually glazed, this covering is given to them more with the view of imparting an attractive appearance than of preserving them from the action of liquids. When properly made and baked, stoneware is sufficiently hard to strike fire from a flint, and is as durable as porcelain.

12. The translucency of porcelain arises from the vitrification of one of the constituents of the paste in the process of baking. The constituents being much more refractory, the article still

retains its form, just as a porous vessel such as a flower-pot would, if it were thoroughly saturated with water. The semi-transparency of porcelain thus produced is an effect of the same class as that imparted to paper or linen cloth by saturating it with melted wax. The vitrifiable constituent which thus renders porcelain translucent is generally the felspar; in some cases, however, it is lime which, entering into combination with the alumina and silica of the clay, forms a double silicate of alumina and lime, more fusible still than the simple silicate of alumina. The oxide of iron produces a like effect, but as it gives a colour to the paste, it can only be used in the commoner sorts of ware. By increasing the proportion of the vitrifiable constituent, greater translucency is imparted to the ware, but the body becomes less plastic, more liable to distortion, and more difficult to work.

13. It is most necessary to comprehend the distinction between the hard porcelain, the manufacture of which, as we have stated, was carried on at a very early date in the East, and the varieties of tender porcelain. The body of the latter sorts is more fusible than that of the former. This property is given to it by introducing into it a larger proportion of alkaline constituents, either in the form of felspar, or of alkaline silicate, prepared expressly for the purpose, and called *frits*. The glaze used for these porcelains is also more fusible than that of hard porcelain, a quality which it receives from a certain proportion of the oxide of lead which enters into its composition.

In certain sorts of tender porcelain no clay whatever is used, and the entire body consists of an artificial *frit*. Such ware, however beautiful it may be rendered in external form and appearance by fine workmanship and rich ornamentation, cannot properly be called porcelain at all. It is at best only an ingenious imitation of that article, bearing to it the same relation as a gilded article bears to a gold one. Nevertheless, such is the article so much admired and so highly prized under the denomination of the "Old Sèvres Porcelain."

14. The English porcelain, and certain sorts still produced in some of the private manufactories of France, belong to the class of tender porcelain, though not all identical with, or even resembling, the Old Sèvres Porcelain. The English porcelain is composed chiefly of clays found in Cornwall, Devon, and Dorsetshire. The Cornish is the best quality, and is technically termed by potters "china clay;" it enters very extensively into the composition of the best kind of ware. It is the decomposed felspar of the granite, and is prepared by the clay merchants themselves in Cornwall, prior to its being sent to the potteries. Huge masses of white granite abound in Cornwall, which is in some parts found partially decomposed;

and when this is the case, the mineral is raised and prepared for the potter's use.

15. The following is the method of preparation:—The stone, having been broken by a pickaxe, is laid in a stream of running water: the light argillaceous parts are thus washed off and kept in suspension; the quartz and mica being separated are allowed to subside near the place where the stone was first raised. At the end of these rivulets are a kind of catchpools, where the water is at last arrested, and time allowed for the pure clay with which it is charged to form a deposit, which, being effected, the water is drawn off; the clay is then dug up in square blocks and placed upon a number of strong shelves, called "linnees," so fitted as to allow of the free circulation of air, that the clay may be properly dried. Thus prepared, it is an extremely white mass, capable by being crushed to be reduced to a fine impalpable powder. In this state it is sent to the potteries under the name of China clay.

16. One of the departments of this manufacture, in which England has of late years gone considerably in advance of the continent, is that devoted to the fabrication of statuary porcelain. This beautiful branch of reproductive art has been almost created within the last six or seven years by some of the most eminent and enterprising establishments in Staffordshire.

Like all novelties in the arts, this process has undergone a succession of improving changes. At first the statuary material was limited to a thin superficial coating laid upon a common body. At present, however, the object is composed of one homogeneous mass of statuary porcelain. The articles thus produced are superior in quality, but much more difficult of manufacture, owing to the much greater degree of contraction which takes place in the oven, and the consequently increased chances of distortion and fracture, especially in pieces of complex form and considerable magnitude. The contraction of the linear dimensions amounts to as much as a fourth of the original magnitude, so that a figure, which as moulded or cast is four feet high, comes out of the oven definitively only three feet in height, the other dimensions being decreased proportionally. The actual contraction in the cubical dimensions which corresponds to this is more than one half, so that the baked materials are included in less than half the space occupied by the unbaked.

17. The process by which statuary porcelain is produced is that called casting, and it resembles in many respects that by which casts of objects are produced in metal.

If the object to be produced is such as can be cast in a single *piece*, a mould of its form is made in plaster of Paris, consisting of *two parts* which can be united by perfectly plane and smooth

surfaces, each part having a sunk impression of one side of the intended object. A clear enough notion of such a mould may be obtained from a common bullet-mould.

When the two parts of the mould are brought into contact, it will leave within it a hollow space corresponding exactly in form with the intended figure, but having a small opening through which the liquid may be introduced.

The statuary paste is brought, by mixture with about its own weight of water, to the consistency of a thick cream, and being well and carefully mixed, so as to be quite homogeneous, it is poured into the mould, which is kept full of it for a certain time, more or less according to the thickness which it is desired to give to the statuary material composing the object. While it thus stands, the bibulous quality of the plaster mould causes it to imbibe water from that portion of the creamy liquid or "slip," as it is called, which is in contact with it, so that a coating of paste, in a sufficiently dry state to have coherence, remains attached to the surface of the mould. Within this is contained that portion of the slip which still remains in the liquid state. This being discharged through a small hole in the mould, provided for that purpose, the mould remains lined with a solid coating of the porcelain paste of a certain thickness.

If it be desired to render the coating upon the mould thicker, so as to give greater strength and weight to the object moulded, the process is repeated; and, in order to equalise the thickness of the deposit, the mould, if it be not too large, is reversed in its position each time that it receives a new charge of slip.

When the mould, by this process, has received a coating of sufficient thickness it is opened, and the object thus cast taken out of it; which is easily accomplished, since no adhesion takes place between its surface and that of the mould.

The thickness of the article thus formed may be varied within practical limits, from that of the egg-shell to the thickness required by objects of the largest attainable dimensions. A beautiful application of this process is practised in the continental factories, by which a thin, delicate article is produced, called egg-shell porcelain.

When a large figure, or group of figures, is to be produced, the process is more complex. Let us suppose its height in the model to be twenty-four inches. Separate and independent moulds are previously made for various parts of the piece, and in the larger and more complex subjects the number of these sometimes amounts to forty or fifty.

Supposing the figure or group to measure twenty-four inches in height as moulded, the shrinking that occurs before these casts

can be taken out of the mould, which is caused by the absorbent nature of the plaster of which the mould is composed, is equal to a reduction of one inch and a half in the height. These casts are then put together by the "figure-maker;" the seams consequent upon the marks caused by the subdivisions of the moulds being carefully removed, the whole is worked upon to restore the cast to the same degree of finish as the original model. The work is then thoroughly dried, to be in a fit state for firing, since, if it were put in the oven while damp, the sudden contraction consequent upon the great degree of heat to which it would be suddenly exposed, would be very liable to cause it to crack: in this process it again suffers a further loss of one inch and a half by evaporation, and it is now but twenty-one inches high. Again, in the "firing" of the bisque oven, its most severe ordeal, it is diminished three inches, and is then but eighteen inches high, being six inches or one-fourth less than the original. It loses, therefore, in the entire process, one-fourth of its linear, and therefore more than one-half of its cubical dimensions. Nevertheless, such is the consummate skill brought to bear on this beautiful manufacture, that in good specimens there is not the slightest discoverable distortion or defect of form or outline.

The perfection to which this branch of the potter's art has recently attained, is such as to render it probable that it will eventually be to sculpture what engraving has been to painting, but with a much closer affinity, identity of colour and texture being attained, as well as that of outline and design.

18. The enamel colours used in the ornamentation of porcelain are produced by certain oxydes of the metals combined with other substances, called *fluxes*, which have the effect of facilitating their fusion. Thus the oxyde of gold produces tints of red, such as crimson, rose-red, and purple. Reds are also produced by the oxydes of iron and chrome. The same oxydes, as well as those of cobalt and manganese, produce blacks and browns; those of uranium, chrome, antimony, and iron produce orange; those of chrome, and copper, green; and those of cobalt and zinc, blue. The fluxes for these various oxydes are borax, flint, oxyde of lead, &c.

These colouring materials are worked up with essential oils and turpentine, and a very great disadvantage under which the artist labours is, that the tints upon the palette are in most cases different to those they assume when they have undergone the necessary heat, which not only brings out the true colour, but also by partially softening the glaze and the flux, causes the colour to become fixed to the ware. This disadvantage will be immeately apparent in the case where a peculiar delicacy of tint is

required, as in flesh tones, for instance. But the difficulty does not end here, for, as a definite heat can alone give to a colour a perfect hue, and, as the colour is continually varying with the different stages of graduated heat, another risk is incurred—that resulting from the liability of its receiving the heat in a greater or less degree, termed "over-fired" and "short-fired." As an instance of its importance we will cite rose-colour, or crimson, which, when used by the painter, is a dirty violet or drab; during the process of firing it gradually varies with the increase of heat, from a brown to a dull reddish hue, and from that progressively to its proper tint. But if by want of judgment or inattention in the fireman, the heat is allowed to exceed that point, the beauty and brilliancy of the colour are destroyed beyond remedy, and it becomes a dull purple. On the other hand, should the fire be too slack, the colour is presented in one of its intermediate stages, as already described; but in this case extra heat will restore it. Nor must we forget to allude to the casualties of cracking and breaking in the kilns by the heat being increased or withdrawn too suddenly, a risk to which the larger articles are peculiarly liable. These vicissitudes render enamel painting in its higher branches a most unsatisfactory and disheartening study, and enhance the value of those productions which are really successful and meritorious.

In enamelling, ground-laying is the first process in operating on all designs to which it is applied; it is extremely simple, requiring principally lightness and delicacy of hand. A coat of boiled oil adapted to the purpose being laid upon the ware with a pencil, and afterwards levelled, or as it is technically termed "bossed," until the surface is perfectly uniform; as the deposit of more oil in one part than another would cause a proportionate increase of colour to adhere, and consequently produce a variation of tint. This being done, the colour, which is in a state of fine powder, is dusted on the oiled ground with cotton wool; a sufficient quantity readily attaches itself, and the superfluity is cleared off by the same medium. If it be requisite to preserve a panel ornament, or any object white upon the ground, an additional process is necessary, called "stencilling." The stencil (generally a mixture of rose-pink, sugar, and water) is laid on in the form desired with a pencil, so as entirely to protect the surface of the ware from the oil, and the process of "grounding," as previously described, ensues. It is then dried in an oven, to harden the oil and colour, and immersed in water, which penetrates to the stencil; and, softening, the sugar is then easily washed off, carrying with it any portion of colour or oil that may be upon it, and leaving the ware perfectly clean. It is sometimes necessary,

where great depth of colour is required, to repeat these colours several times. The "ground-layers" do generally, and should always, work with a bandage over the mouth, to avoid inhaling the colour-dust, much of which is highly deleterious. Bossing is the term given to the process by which the level surfaces of various colours, so extensively introduced upon decorated porcelain, are effected. The "boss" is made of soft leather.

The process of gilding is as follows:—The gold (which is prepared with quicksilver and flux), when ready for use, appears a black dust; it is used with turpentine and oils similar to the enamel colours, and, like them, worked with the ordinary camel's-hair pencil. It flows very freely, and is equally adapted for producing broad massive bands and grounds, or the finest details of the most elaborate design.

To obviate the difficulty and expense of drawing the pattern on every piece of a service, when it is at all intricate, a "pounce" is used, and the outline dusted through with charcoal—a method which also secures uniformity of size and shape. Women are precluded from working at this branch of the business, though, from its simplicity and lightness, it would appear so well adapted for them. Firing restores the gold to its proper tint, which first assumes the character of "dead gold," its after brilliancy being the result of another process termed "burnishing." *

19. The ornamentation of the less costly descriptions of ware, such as are in common use for the table, and in which a single colour only is used, is accomplished by a process similar to that of copper-plate printing. There are two methods of effecting this, one called "press," and the other "bat" printing. In "press" printing the design is formed on the article before it receives the glaze, and is afterwards covered and protected by the glaze, through which, being quite transparent, it is visible. In "bat" printing, on the other hand, the design is laid upon the glaze, and fixed there by enamelling it.

In both cases the design is first executed on a copper-plate. For press printing it must be cut very deep to enable it to hold a sufficiency of colour to give a firm and full transfer on the ware. The printer's shop is furnished with a brisk stove, having an iron plate upon the top, immediately over the fire, for the convenience of warming the colour while being worked, also a roller, press, and tubs. The printer has two female assistants, called "transferrers," and also a girl, called a "cutter." The copper plate is charged with colour, mixed with thick boiled oil, by means of a knife and "dabber," while held on the hot stove plate, for the purpose of

* Official Catalogue of the Great Exhibition, p. 713.

keeping the colour fluid; and the engraved portion being filled, the superfluous colour is scraped off the surface of the copper with the knife, which is further cleaned by being rubbed with a "boss," made of leather. A thick firm oil is required to keep the different parts of the design from flowing into a mass, or becoming confused, while under the pressure of the rubber in the process of transferring. A sheet of paper, of the necessary size and of a peculiarly thin texture, called "pottery tissue," after being saturated with a thin solution of soap and water, is placed upon the copper plate, and being put under the action of the press, the paper is carefully drawn off again, the engraving being placed on the stove, bringing with it the colours and design with which the plate was charged. The paper is then laid upon the ware, and rubbed upon it with flannel. During this friction the coloured design upon the paper is partly imbibed by the unglazed surface of the ware, and partly remains upon that surface. The article is then immersed in water, by which the paper being softened, and partially dissolved, it is easily washed off with a sponge, the coloured design alone remaining on the surface of the article. The oil included in the colouring matter is then expelled by exposure to heat in a kiln, called a hardening kiln, after which the design being left in perfectly dry colouring matter, the article is glazed. When covered with the raw glaze, the design is quite invisible, the glaze being opaque in that state; but when it is vitrified in the oven, it becomes quite transparent, and the design is apparent through it.

The bat printing is done upon the glaze, and the engravings are for this style exceedingly fine, and no greater depth is required than for ordinary book engravings. The impression is not submitted to the heat necessary for that in the bisque, and the medium of conveying it to the ware is also much purer. The copper plate is first charged with linseed oil, and cleaned off by hand, so that the engraved portion alone retains it. A preparation of glue being run upon flat dishes, about a quarter of an inch thick, is cut to the size required for the subject, and then pressed upon it, and being immediately removed, draws on its surface the oil with which the engraving was filled. The glue is then pressed upon the ware, with the oiled part next the glaze; and being again removed, the design remains, though, being in a pure oil, scarcely perceptible. Colour, finely ground, is then dusted upon it with cotton wool, and a sufficiency adhering to the oil leaves the impression perfect, and ready to be fired in the enamel kilns.

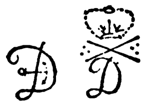
20. It has been the practice at all the great porcelain manufactories to stamp upon the bottom, or some other convenient

part not exposed to view, of each article fabricated, a peculiar distinctive mark, by which the place of its manufacture shall be always capable of being ascertained. It will not be without interest here to indicate some of the principal of these marks.

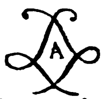
The Dresden porcelain, manufactured at the royal manufactory of Meissen, bears the mark of two swords crossed, as here represented.

The English porcelain, manufactured at the celebrated Chelsea works, is marked with an anchor, thus 

The porcelain manufactured at Derby is marked with the cypher



The old Sèvres porcelain, fabricated from 19th Aug., 1753, until the fall of Royalty in 1793, is marked with the cypher



During the Republic, from 1793 until the end of 1800, the mark over the Sèvres porcelain was simply the initials F. R.

From 1800 to 1804 the articles were marked with the characters,

M . N^{le} (Manufacture Nationale).
Sèvres
— ıı =

During the Empire, 1804 to 1814, the words Manufacture Impériale, Sèvres, were stamped upon the porcelain.

From the Restoration to the Revolution of 1830, the articles bore the royal cipher, the double L or double C.

From 1830 to 1834, the symbol of equality, a double equilateral triangle was used: and from 1834 to the Revolution, 1848, the articles bore the cipher of Louis Philippe.

By these indications the amateur will be enabled to determine the epoch of the manufacture of such articles as may fall under his notice.

21. There is nothing more remarkable in this branch of industry than the great number and variety of unexpected uses to which the ingenuity of the manufacturer has rendered it subservient. At the Great Exhibition of 1851, this was especially conspicuous. Among the specimens there collected were found, for example, chimney-pieces of statuary porcelain. The advantages of this application are numerous and obvious. Among them are great durability and freedom from the susceptibility of discoloration and staining to which marble is liable. Plateaux and slabs for the covering of fire-places, tops of console toilet and chess-

tables, panels of doors and window-shutters, tiles for flooring and walls, terra-cotta for vases and garden pots, are among the many productions of this art.

Encaustic tiles for ornamental flooring merit especial notice. This branch of the earthenware manufacture has recently acquired considerable importance, and an export business of some extent has been already established in it. Large quantities of this article are now exported to the United States and the colonies, as well as to certain parts of Europe. The palace of the Sultan at Constantinople is paved with this tiling, as are also the House of Lords, Osborne House, and St. George's Hall, Liverpool. This flooring has got into very general use in churches, private mansions, conservatories, &c. It is as durable as marble, less liable to stains, and can be decorated with any design to suit the taste of the purchaser.

As a specimen of pottery on a large scale, the figure of Galatea, seven feet high, is deserving of attention. This claims to be the largest perfect object in pottery which has yet been produced in a single piece. Attempts are, we understand, being made, with some probability of success, to produce it in statuary porcelain.

Among the ornamental and merely artistic applications of this art, we must not omit to notice the copies of paintings, often upon a very large scale, made in enamel colours upon slabs of porcelain. These beautiful productions of the ceramic art proceed almost exclusively from the national manufactories of France and Saxony.

The portraits of the Queen and Prince Albert, which were exhibited in the great aisle of the Crystal Palace, are fine specimens of the largest porcelain paintings which have been produced at the Sèvres manufactory. These are half-length portraits of the size of life, each painted on a single slab of porcelain. They are copies of the well-known portraits by Winterhalter, and were executed by order of Louis Philippe, and presented to her Majesty. These works were commenced before the revolution of 1848, but not finished until after that event. Louis Philippe claimed them as his private property, and they were surrendered to him by the Republican Government; but the portrait of Prince Albert had met with an accident, by which it was broken. Louis Philippe desired to have another made, but the Queen would not hear of this expense being incurred; and the fracture being repaired at Sèvres, the portraits were sent to England and delivered to her Majesty. The portrait of her Majesty is by A. Ducluzeau, and that of Prince Albert by A. Bezanget.

Among the splendid collections of paintings and vases exhibited

by the national manufactory of Sèvres, at the Great Exhibition, the most valuable and most worthy of attention and examination were the following:—

The painting of the Virgin, known as the *Vierge au Voile*, by Madame Ducluzeau, was copied from the celebrated picture by Raffaelle in the Louvre. The porcelain is of the same magnitude as the original, and measures 26 inches by 19. This work was executed in 1847-8, price 1000*l.* Another painting after Tintoretto, on a plate of porcelain 45 inches high, by Madame Ducluzeau, price 880*l.* A flower subject on a plate of porcelain, 40 inches high, by M. Jacober, 800*l.* A portrait of President Richardeau, by M. Beranger, 440*l.* A portrait of Vandyck, by Madame Ducluzeau, 280*l.* A painting on a plate of porcelain, eight inches high, reduced from Raffaelle's "Madonna," by M. Constantin, 100*l.*

Fig. 43.—BAKING ROOM IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER V.

1. Process of throwing.—2. Turning.—3. Moulding.—4. Turning and Moulding combined.—5. Glazing.—6. Bisque firing.—7. Ovens.—8. Sèvres ovens.—9. Statistics of pottery.

1. The brief explanation of some of the processes by which the beautiful productions of this branch of industry are obtained, which have been given in the preceding pages, will be easily understood by all persons who may have had the pleasure and advantage of visiting any of the great porcelain-works. For the benefit of those who have not been so fortunate, we shall here give some more developed explanations of the succession of processes by which the raw clay is converted into the finished article; in doing which we shall avail ourselves of some admirably executed sketches, showing the interior of some of the principal workshops of a porcelain factory, which were prepared under the direction of the late M. Brongniart, director of the Royal porcelain works of Sèvres, and executed by Mr. Charles Develey, an artist

employed in the establishment, who possessed, according to M. Brongniart, in a high degree, the talent of seizing with the greatest truth and exactitude the characteristic habits of each class of operatives, and their peculiar attitudes and movements in the execution of their work.

It will be remembered that the materials out of which the potter produces the articles of his fabrication are 1° kaolin, or china clay, and 2° flints. The former ingredient, as has been already explained, is prepared by the clay merchant in Cornwall, or whatever other place the clay is found, and is delivered to the potter ready to be mixed with the flint earth. But the latter is prepared from the natural flints in the potteries by the following process:—

The flint stones are first calcined, and this is effected in a kiln similar to that used for lime-burning. These stones are separated by alternate layers of coal, and the burning usually occupies about twenty-four hours. The flints are then very white and very brittle, and ready to be crushed by the "stamper," a machine composed of upright shafts of wood, six feet long, and about eight inches square, heavily loaded with iron at the lower end, which, by means of applied power, are made to rise and fall in succession on the flints, contained in a strong grated box. It is then removed to the grinding vats, which are from twelve to fourteen feet in diameter, and four feet deep, paved with chert stone, large blocks of which, being also worked round by arms connected with a central vertical shaft, propelled by an engine, become a powerful grinding medium. This peculiar stone is used because of its chemical affinity to the flint, which, therefore, suffers no deterioration from the mixture of the abraded particles, which necessarily results from the friction, a matter of serious moment. In these vats the flint is ground in water until it attains the consistency of thick cream, when it is drawn off and conveyed by troughs into the washing chamber. Here it undergoes a further purification; more water is added, and it is kept in a state of gentle agitation, by means of revolving arms of wood, thus keeping the finer particles in suspension while the liquid is again drawn away in pipes to a tank below. The sediment is afterwards re-ground. The cleansing process is not yet complete, for when the fluid has passed into these tanks, to about half their depth, they are filled up with water, which is repeatedly changed, until it is considered sufficiently fine, and free from all foreign matters: it is then fit for use.

The next process consists in mixing the clay with the flint. This is accomplished by mixing both with water, so as to give them a creamy consistency, and to convert them into what the

potters technically call *slip*. For this purpose the two slips, that of clay and that of flint, are successively run off into the blending reservoir, against the inner side of which are "gauging rods," by which the necessary proportion of each material is regulated. The mixture is now passed into other reservoirs, through fine sieves on "lawns," woven of silk, and containing 300 threads to the square inch. A pint of slip of Dorsetshire or Devonshire clay weighs 24 ounces, of proper consistence; of Cornish clay 26 ounces; and of flint 32 ounces. Finally, the slip is conveyed to a series of large open kilns, heated underneath by means of flues, and about 9 inches deep. The excessive moisture is thus evaporated, and in about twenty-four hours the mixture becomes tolerably firm in substance. It is then cut into large blocks and conveyed to an adjoining building to undergo the process of "milling." The mill is in the form of a hollow cone, inverted, with a square aperture or tube at the lower part. In the centre is a vertical shaft, set with broad knives. When this shaft is in action (worked by steam power), the soft clay is thrown in, and forced downwards, being alternately cut and pressed until it exudes from the aperture at the bottom, in a perfectly plastic state, and ready for the hand of the potter.*

The paste thus prepared would serve for the purposes of manufacture, but it is found that it may be considerably improved by leaving it for an interval, more or less protracted, several years for example, stored in damp vaults or cellars. It suffers a sort of *rotting*, becomes black, and evolves an offensive odour of the gas called sulphuretted hydrogen. These effects are easily explained. The paste, as prepared, always contains a proportion, however minute, of organic matter, which the previous preparation has failed to extricate from it. This matter by the influence of the humid air, undergoes a spontaneous combustion, and acting upon some traces of sulphates, which also remain as unextricated impurities in the paste, transforms them into sulphurets, and accordingly sulphuretted hydrogen is evolved.

The utility of all these processes, by which the minutest particles of organic matter are disengaged from the dough, will be understood when it is considered that even the presence of a single hair in the dough would be sufficient to spoil completely an article of porcelain of great beauty and value; for the organic matter thus buried in the material being decomposed by the action of the ovens, a gas would be developed which would produce air-bubbles or even cracks in the article.

To work the paste, when ready for the manufacture, it is once

* Catalogue of the Great Exhibition, p. 718.

more tempered by the potter, who for that purpose divides it into balls of convenient size , which he *slaps* with great force upon his table. The last air-bubbles are expelled from the dough by this process.

The formation of the dough into the fabricated article is effected, either by the processes of *throwing* and *turning* on the wheel, or by moulding, the latter being effected either by *pressure* or by *casting*.

The process of forming the article on the potter's wheel has been briefly explained in a former chapter. It will be more clearly comprehended by the aid of M. Develey's sketch of the thrower and turner's shop, represented in fig. 28 at the head of Chapter III.

A ball of dough is given to the thrower, A, of sufficient magnitude for the piece intended to be made. He places it on the centre of the circular plaster disc, which is attached to the top of his wheel, and which revolves with the wheel. By the dexterous application of his hands and fingers, the ball of dough passing through a succession of forms assumes ultimately that which is desired.

Some idea may be formed of this most ancient and characteristic operation of the potter's art by the aid of the diagrams, fig. 29 to fig. 34.

Let it be supposed that the shape of the vase to be formed is that represented in fig. 29. It will then be produced in two

Fig. 29.

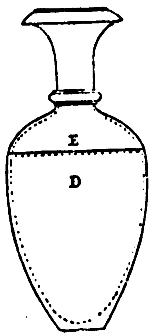


Fig. 30.

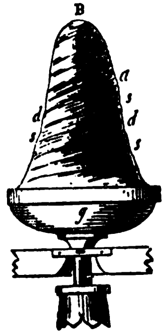
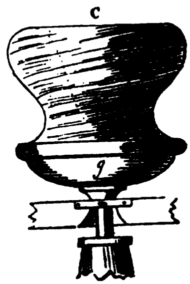


Fig. 31.



separate pieces, D and E, which after being formed on the wheel must be united and attached one to another by that general cement of the potter called SLIP.

A ball of dough, B, fig. 30, sufficient to produce the lower part D, fig. 29, being placed on the wheel and put in rotation, is shaped

by the hands and fingers of the thrower, assuming successively the forms, C, fig. 31, and D, fig. 32, the shape of the hollow part or interior being indicated by the dotted line. The traces of the fingers appear in the spiral lines, *d s*. The circular disc forming the top of the wheel is represented at *g*.

The ball of dough, A, fig. 33, after similar manipulation, takes the form, E, fig. 34. The parts D and E being united, the superfluous part of the dough is turned off so as to give the desired form to the external surface.

Fig. 32.

D

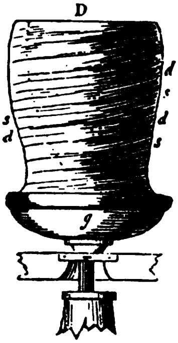


Fig. 33.

A

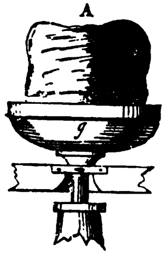
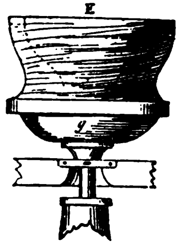


Fig. 34.

E



The peculiar attitude of the arms of the thrower, which is well represented in fig. 28, will be observed to bear a close resemblance to that represented in the ancient Egyptian drawing, fig. 5.

2. When the *thrown ware*, as it is called, which is thus produced, has been rendered sufficiently consistent by spontaneous air drying, it is transferred to the hands of the turner, who is represented at B, fig. 28, and who works at a wheel similar to the ordinary potter's wheel. This operative, by means of a cutting tool, renders the form of the article more exact and true, and shaves off all roughness and inequalities by a process precisely similar to that of turning with the ordinary lathe, only that in the present case the axis of the lathe is vertical, and the circular motion imparted to the article horizontal. The shavings which are detached in this process are mixed with fresh paste, to which they impart peculiar qualities.

Various tools and accessories appear in the figure, such as the gauge compasses, calipers, *c*, by which the diameter of the vase at different points is measured, the working drawing, *d*, which gives him both the profile and the dimensions, the latter being from time to time verified with the calipers.

3. The moulder's shop is represented in fig. 35, at the head of Chap. IV.

The work of the moulder consists of two processes; *first*, to impart the desired form to the piece; and *secondly*, to adapt and attach to the principal piece its various accessories, which are separately moulded or cast, such as handles, spouts, ears, &c.

The operative, A, places on a marble slab before which he stands a mass of dough which he flattens with a rolling-pin. Each end of the pin rests upon a lath by which it is prevented from pressing the dough below a certain thickness, and which also gives it a perfectly even motion, so that the cake of dough is not only of uniform thickness, but has also a perfectly even and uniform surface. This uniformity of surface on the under side it receives by pressure on the slab, and on the upper side by the regulated action of the roller.

Under the cake of dough, and between it and the slab, is previously spread a cloth, *b*, upon which it rests. By means of this cloth the operative is enabled to raise the dough from the slab without deranging its form.

The operative, B, having received it from A, thus supported by the cloth *b*, places it upon the mould, which, as here represented, will produce the inner or concave surface of a vase or cup, having a sort of fluted form. When the mould is completely covered with the dough, the operative, C, presses the dough strongly upon it with a sponge, so as to force it into exact contact with the most minute cavities of the mould. To accomplish this the more easily, the mould is placed upon the circular slab, *p*, supported on a vertical pillar, *f*, with which it turns freely, so that every side of the article to be moulded is brought successively under the hand of the operative.

Plates, dishes, and saucers, and in general the class of articles denominated "flat ware," are made from moulds, by which the inside or concave surface of the article is formed. The form is imparted to the convex surface by means of profiles usually made of fired clay and glazed. After the proper convex form is given by the turner C by means of the profile, the mould, with the article still upon it, is taken to the hot-air chamber, where it remains till it is tolerably dry. It is then brought back to the turner C, and the profile is again passed over it, by which the inaccuracies of form consequent upon shrinkage are corrected.

The operative, G, has just moulded or cast a handle from which he is removing the superfluous and excrescent parts a tool, and cleaning out its cavities. He is about to attach e, as he has already done with the other handle. nplishes by moistening, with the creamy liquid

called *slip*, the surfaces to be united. This slip acts as a cement, becoming almost immediately hard enough to retain the handle in its place.

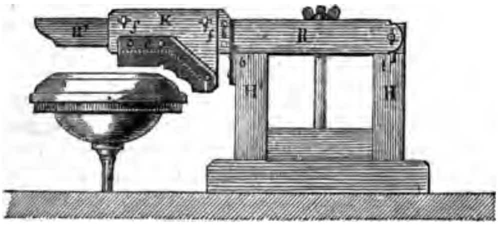
A number of handles ready moulded or cast are lying on the slab beside G, ready to be attached to similar articles. Various plaster moulds appear on the floor near the table.

The convex surface of the article to be moulded is produced in like manner, by pressing a concave mould upon it. Some of these concave moulds appear on the floor.

The process of moulding by casting has been explained in the case of statuary porcelain.

4. The operations of the thrower and moulder are sometimes abridged by combining them. The apparatus represented in fig. 36 supplies an example of this.

Fig. 36.



It consists of a porte-calibre, K, and a copper bar, RR′, which plays on a hinge or pivot, at one extremity, and is supported on a frame, HH′, of wood solidly attached to the table of the wheel. It is raised and lowered by turning it on the hinge, *t*, and when lowered is supported on the upright H′ at *t′*. The porte-calibre slides on this, its motion being regulated by a groove. To this is attached by screws the "calibre," or profile, *c*, which is formed to correspond with the shape and mouldings of the article to be produced.

The mould which gives the form to one side of the article, (suppose for example the concave or upper surface of a plate,) being attached to the disc of the potter's wheel, a cake of dough of the proper magnitude and thickness is laid over it, and pressed upon it by a wet sponge, so as to cause it to apply itself closely at every part to the surface of the mould. When this is accomplished the calibre or profile is lowered gradually upon it, and the wheel being put in revolution, the convex side or bottom of the plate receives its form in the same manner as an object placed in the chuck of a turner's lathe is shaped by a cutting tool guided by a slide-rest.

By this process the article receives a perfectly uniform thickness and diameter, the edges being subsequently rounded on the wheel in the usual way.

5. Ware which has received its proper forms by the processes above described and which has been to a certain degree hardened by air drying or exposure to a high artificial temperature, is in what is called by potters the *green* state. It is completely dry, all moisture being perfectly expelled from it, but is still very porous, so that it would readily imbibe water or other liquid which might be poured into it, or in which it might be immersed. It is in this state that the process of glazing, already described, must be executed.

The materials comprised in the various glazes commonly used for china and earthenware are—Cornish stone, flint, white lead, glass, whiting, &c. These, having been ground together in proper proportions to the consistence of milk, form the glaze. The process is effected in large buildings termed "dipping-houses" (china and earthenware being kept separate), fitted up with tubs for the glaze, and stages for the reception of the ware when dipped, upon which it is dried and heated, generally by means of a large iron stove or "cockle," from which iron pipes, extending in various directions, convey the heat throughout the whole extent of the "houses." Each dipper is provided with a tub of glaze, in which he immerses the bisque ware. We may note the results of practice and experience in imparting a facility and dexterity of handling, so necessary to perfection in this process. The ware is held so that as small a portion as possible shall be covered by the fingers; it is then plunged in the glaze, which, by a dexterous jerk, is made not only to cover the entire piece, but, at the same time, so disperses it, that an equal and level portion is disposed over the whole surface, which, being porous, imbibes and retains it. The ware is handed to the dipper by a boy, and another removes it when dipped to the drying or "hot-house." The glaze is opaque till fired, so that the design of pattern executed on the bisque is completely hid, after dipping, till they have been submitted to the glost fire. An able workman will dip about seven hundred dozen plates in a day.*

The dipping house is represented in fig. 37. The dippers, A, and B, immerse unglazed plates in the vessel containing the glaze, which, as already explained, is a creamy liquid in which the vitrifiable matter is mixed, and held in suspension, just as mud is in water. When the plate is withdrawn from the glaze it is held over it so as to allow all the liquid not absorbed by the plate to drip off, as represented in the case of the dipper B.

* Catalogue of the Great Exhibition, 725.

The females C and D are employed in detaching from articles which have been dipped the parts of the glaze which are redundant. Thus C scrapes off, with a bladed tool, a portion of the glaze where it is too thick, or where it remains attached to the surface in round drops called *tears*. The other, D, removes with a brush or a piece of felt the glaze from the circular ring at the bottom of a plate, that being the part on which it stands when placed in the oven. If this precaution were not taken, the plate would

Fig. 37.

adhere to the oven by means of the portion of glaze on this circular edge when vitrified.

When the articles are thus prepared, they are put into an oven where they are exposed to a temperature which vitrifies the glaze upon their surface.

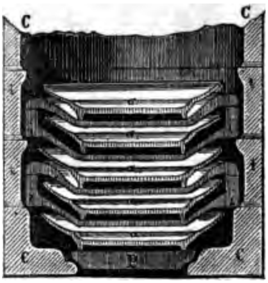
It is necessary that the glaze thus applied to the article should be such as will vitrify at a temperature lower than that which would soften the paste of which the article is made, and thus deform the article itself.

In the figure are seen several tools and utensils used in the process of glazing. Thus *g* is the wooden grating upon which the article is left to drip after being withdrawn from the glaze; *t* is a

sieve which is used to strain off any solid impurities which may be seen floating in the glaze; *p* is the spatula used from time to time to agitate the glaze so as to prevent the pulverulent matter suspended in it from subsiding, and to maintain it of an uniform consistency. A bottle, *b*, contains vinegar, which is mixed in a certain proportion with the glaze; a small cup, *c*, containing liquid glaze is placed near the female D, who dipping a brush in it retouches all parts of the article on which the glaze is too thin or altogether wanting.

6. When the wares have been prepared for the final process of baking, which is called technically *bisque firing*, they are carried on boards as represented in fig. 43, to the "green-house," so called from its being the receptacle for ware in the "green" or unfired state. It is here gradually dried for the ovens: when ready, it is carried to the "sagger-house," in immediate connexion with the oven in which it is to be fired, and here it is placed in the "saggers:" these are boxes made of a peculiar kind of clay (a native marl), previously fired, and infusible at the heat required for the ware, and of form suited to the articles they are to contain. A little dry pounded flint is scattered between them, to prevent adhesion. The purpose of the sagger is to protect the ware from the flames and smoke, and also for its security from breakage, as in the clay state it is exceedingly brittle, and when dry, or what is called "white," requires great care in the handling. A plate sagger will hold twenty plates, placed one on the other, of earthen ware; but china plates are fired separately in "setters" made of their respective forms. The "setters" for china plates and dishes answer the same purpose as the "saggers," and are made of the same clay. They take in one dish or plate each, and are "reared" in the oven in "bungs" one on the other.

Fig. 38.



In fig. 38 is represented a pile of saggers containing plates. It will be perceived that in this case each sagger consists of two parts, one, *t t*, cylindrical, and the other, *i i*, having a form corresponding to that of the plate, the rim, at the bottom of which rests upon it. These saggers are placed one over the other, so as to form a vertical pile.

It will be evident, from what has been here explained, that the magnitude, form, and internal structure of the saggers

must vary with those of the articles which they are intended to contain.

The disposition and arrangement of the piles of saggers in the oven are represented in fig. 39, some of the piles being represented in section, to show the arrangement of the articles within the saggers.

The process of baking highly decorated ornamental articles in porcelain is a process requiring much greater precaution, and a

Fig. 39.

different sort of apparatus. It is usually effected by means of special furnaces and saggers, of which an example is presented in fig. 40. The furnace is constructed in fire-clay or cast-iron, and the fire is regulated in it with the greatest care. Trial pieces are from time to time taken from the opening, *v*, by which the effect of the firing on the several colours is ascertained.

7. The hovels in which the ovens are built form a very peculiar and striking feature of the pottery towns, and forcibly arrest the attention and excite the surprise of the stranger, resembling as they closely do a succession of gigantic bee-hives. They are constructed of bricks, about 40 feet diameter, and 35 feet high, with an aperture at the top for the escape of the smoke. The "ovens" are of a similar form, about 22 feet diameter, and from 18 to 21 feet high, heated by fire-places, or "mouths," about nine in number, built externally around them. Flues in connection with these converge under the bottom of the oven to a central opening,

drawing the flames to this point, where they enter the oven: other flues, termed "bags," pass up the internal sides to the height of about four feet, thus conveying the flames to the upper part.

Fig. 40.

When "setting in" the oven, the firemen enter by an opening in the side, carrying the saggers with the ware placed as described: these are piled one upon another from bottom to top of the oven, care being taken to arrange them so that they may receive the heat (which varies in different parts) most suited to the articles they contain. This being continued till the oven is filled, the aperture is then bricked up: the firing of earthenware bisque continues sixty hours, and of china forty-eight.

The quantity of coals necessary for a "bisque" oven is from 16 to 20 tons; for a "glost" oven from 4½ to 6 tons.

The ware is allowed to cool for two days, when it is drawn in the state technically termed "biscuit," or bisque, and is then ready for "glazing," except when required for printing, or a common style of painting, both of which processes are done on the "bisque" prior to being "glazed."

8. A porcelain oven of three stages, used in the Sèvres manufactory, is represented in fig. 41 and fig. 42, the former being the exterior view, and the latter a vertical section by a plane through its centre. Each of the lower stages, L and L′, is heated by four furnaces, from which the flame and heated air is drawn into the oven through the flues *g*. Fire-doors of plate-iron are provided, by which the mouths of the furnaces and ashpits can be closed or opened at pleasure.

When the several stages of the ovens are charged with the wares to be baked, the firing is conducted so as to raise the temperature by slow and regulated gradation. The fires, at first moderate in their force, are constantly augmented for from sixteen to twenty hours. When the oven is thus well heated, the great firing is commenced by giving full charges of fuel to all the furnaces. The oven itself, which is cylindrical below, terminating nical roof with an opening at top, governed by a regulating

plate or damper, *t*, discharges the functions of a chimney, so that the currents of flame and heated air drawn from the furnaces severally entering the oven, circulate around the ware with

Fig. 41.

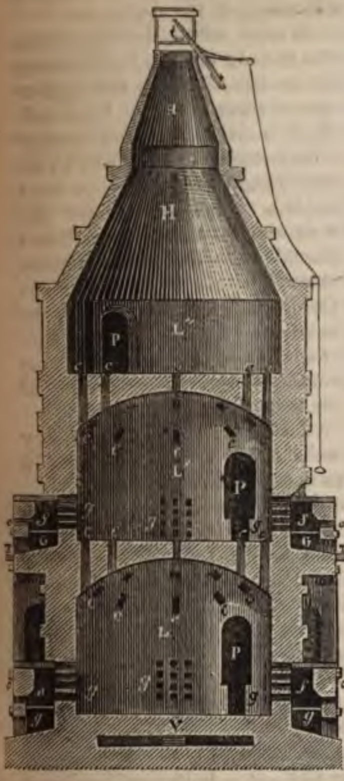


Fig. 42.

which it is charged, and rising to the conical roof, H H, escape at the opening *t*. The current passes from stage to stage through orifices, *c*, *c*, *c*, formed in the flooring for that purpose.

The great firing which completes the process of baking is maintained for ten or twelve hours.

The oven is built with fire-bricks, bound by bracings of iron, as represented in fig. 41. In each stage there is provided a door, P, through which the charge and discharge is made, and which during the process of baking is walled up with brickwork. In

this brickwork small holes, *m m*, are left, through which the oven-man from time to time takes out trial-pieces, which are pieces of clay of known quality, and which indicate by the effect produced upon them the progress which the baking has made. When the appearance of these trial-pieces shows that the firing has been sufficiently continued, the furnace and ashpit doors and the damper *t* are closed, and the oven, with its charge, is left to cool gradually for twenty-four or thirty hours. It is not necessary to delay the withdrawing of the pieces from the oven until they have become quite cold; but the sudden alteration of temperature would occasion them to crack if they were taken out while their heat was greatly above that of the atmosphere.

Some potters are occasionally tempted, when the furnace contains articles of small value, to risk the damage here mentioned, and to withdraw the saggers with their contents without delay, their object being to profit by the heat of the furnace either for introducing a new charge, or for drying a fresh set of saggers. No one, however, would be so improvident as to expose the finer descriptions of porcelain to this hazard, in order to gain any such immaterial advantage.

From the similarity of its appearance to well-baked ship bread, the ware is now called *biscuit*. Its permeability to water when in this state fits it for being employed in cooling liquids. If previously soaked in water, the gradual evaporation from its surface by means of the air, causes an absorption of heat from the surrounding atmosphere, which is again supplied by neighbouring objects, until an equilibrium of temperature is restored.

9. As there are no excise or other regulations affecting the manufacture of earthenware, there are no official documents or records by which the actual extent of the manufacture can be ascertained with precision; but it is estimated that at the Potteries alone the value of the earthenware produced annually is about 1,700000*l*., and that the value of the manufactures of Worcester, Derby, and other parts of the country, may amount to about 750000*l*., making a total annual value of 2,450000*l*.

The value of the gold consumed annually at the Potteries in the ornamentation of porcelain is 36400*l*., and, since about half that amount is consumed in the other seats of the manufacture, it may be stated that the total value of the gold used annually in England in this manufacture is about 54600*l*.

The quantity of coals consumed annually at the Potteries is 468000 tons, and, about half that amount being consumed in other factories, it may be stated at about 700000 tons—an ...unt equal to what is consumed in working all the railways of ...nited Kingdom.*

* See Lardner's Railway Economy, p. 83.

POTTERY STATISTICS.

It appears from the official reports that, in 1841—the latest year in which official returns have been made public—the declared value of the earthenware exported was 600759*l.*; in 1837 the declared value was 563238*l.* In the four years ending 1841, an increase, therefore, took place in this export trade of 37521*l.* upon 563238*l.* If this same rate of increase only has been maintained since 1841, the present annual export trade must have a declared value of a million sterling.

But, since the declared is known to be on an average one-fourth less than the true value, we may assume that the present total annual amount of the export trade in earthenware is about 1,300000*l.*

The proportion in which this enormous export is distributed among the different countries of the world is exhibited in the following table. In the second column is given the proportion of every 100*l.* value exported received by each of the countries named in the first column, and in the third column is given the number of pieces of ware out of 10000 received by each country respectively:—

Countries.	Per Cent. of the total Value.	Per 10000 of Number of Pieces.
United States	37·58	3560
North American British colonies	6·95	778
Brazil	6·36	1010
British East Indies	5·00	310
British West Indies	4·42	387
German States	4·28	401
Holland	4·11	397
Foreign West Indies	3·50	396
Australian colonies	2·69	216
Denmark	2·31	257
Italy and Italian islands	2·25	145
Sumatra, Java, and Indian islands	1·39	168
Spain and the Balearic islands	1·08	145
Western Africa	0·85	73
Cape of Good Hope	0·79	64
Channel Islands	0·69	65
Turkey	0·67	55
Russia	0·65	40
All other countries	14·43	1533
Total	100·00	10000

It appears from this table that the United States is our great foreign customer for this manufacture, taking in value 37½ per cent., and in quantity 35½ per cent., of our entire export. Of the remainder, our North American colonies, Brazil, and India, take 18 per cent.

In 1841, our export in this manufacture formed about 30 per cent. of its estimated total value. We have no returns later, but it is probable that at present the export forms a much larger proportion of the entire value fabricated.

COMMON THINGS.

FIRE.

1. Fire an ancient element.—2. Combustion.—3. Fuel.—4. Carbon.—5. Hydrogen.—6. Charcoal fire.—7. Its effect on the air.—8. Experimental illustration of combustion of charcoal.—9. Combustion of hydrogen.—10. How the combustion is continued.—11. Carbon burns without flame.—12. What is flame?—13. Combustion of hydrogen produces water—14. All combustibles produce carbonic acid and water.—15. Carburetted hydrogen.—16. Carbon renders flame white.—17. Olefiant gas.—18. Light carburetted hydrogen.—19. Fire-damp.—20. Will-'o-the-Wisp.—21. Experimental illustration.—22. Heavy carburetted hydrogen.—23. Pit-coal—24. Coal-fire explained.—25. Products of its combustion.—26. Its effect on the air.—27. Wood-fuel.—28. Combustibles used for illumination.—29. Their effect on the air.—30. Construction of grates and chimneys.—31. Analysis of a common coal-fire.—32. It warms and ventilates.—33. Necessity for ventilation.—34. Injurious effect of plants at night.—35. Effect of crowded and brilliantly lighted rooms.—36. Explanation of the burning of a candle.—37. And of lamps.

1. In the physical theory which prevailed among the ancients, and which maintained its ground for several thousand years, Fire was accounted as one of the elements; that is to say, as a material

essence, which with three others, air, water, and earth, constituted all natural bodies.

It was only towards the close of the last century, and within the lifetime of the elder part of the present generation, that the true character of fire was discovered.

2. It is now known that fire is neither a distinct substance nor essence, as supposed by the ancients. It is a phenomenon consisting of the sudden and abundant evolution of heat and light produced when a certain class of bodies called COMBUSTIBLES enter into chemical combination with the oxygen gas which, as has been explained in our Tract on Air, constitutes one of the constituents of the atmosphere. The term COMBUSTION in the modern nomenclature of physics has been adopted to express this phenomenon.

3. The class of combustible substances which are commonly used for the production of artificial heat is called FUEL. Such, for example, are pit coal, charcoal, and wood.

Another class of combustibles is used for the production of artificial light: such, for example, are oil, wax, and the gas extracted from certain sorts of pit coal, from oil, and from certain sorts of wood, such as the pitch pine.

4. The principal constituents of all these combustibles, whether used for the production of heat or light, are those denominated by chemists CARBON and HYDROGEN.

CARBON is the name given to charcoal when it is absolutely pure, which it never is as it is obtained by the ordinary industrial processes. It is in that state combined with various heterogeneous and incombustible substances. In the laboratories of chemists it is separated from these, and obtained in a state of perfect purity, being there distinguished from the charcoal of commerce by the name CARBON.

Carbon having never been resolved by any chemical agent into other constituents, is classed in physics as a simple and elementary body, which enters largely into the composition of a most numerous class of bodies which are found in nature, or produced in the processes of industry, the sciences, and the arts.

5. HYDROGEN has been already very fully described and explained in our Tract upon Water; we shall presently explain still more in detail its leading properties. Like carbon, it is classed as a simple and elementary substance; and also, like carbon, enters largely into the composition of a numerous class of bodies.

6. A quantity of charcoal being placed in a furnace through which a draught of air is maintained, if a part of it be heated to redness, the entire mass will soon become incandescent, and will reddish light, which will be whiter as the air is passed it more briskly, and will emit considerable heat. The will gradually decrease in quantity, and at length will

disappear altogether from the furnace, under which a small portion of ashes consisting of incombustible matter will remain. If the charcoal had been pure—that is, if it had been carbon—it would have altogether disappeared, no ash whatever remaining.

This phenomenon is an example of FIRE. The heat and light developed during the process here described are commonly called fire.

7. To comprehend what takes place in this process, we must consider that, as the air passes through the charcoal, the oxygen gas, which forms one-fifth part of it,* enters into combination with the pure carbon. A compound is thus formed consisting of carbon and oxygen. The formation of this compound is attended with so great a production of heat, that not only the compound itself, but the charcoal, from which it is evolved, is raised to a very elevated temperature.

The compound thus produced is a gas called carbonic acid, which has been already briefly noticed in our Tract on Air.

The air which enters the furnace being a mixture of azote and oxygen,* that which rises from it after the combustion has been produced is a mixture of azote and carbonic acid; the azote having passed through the furnace without suffering other change than an increase of temperature, while the oxygen has been converted into highly heated carbonic acid.

Several questions, however, arise out of this explanation. How is it known that such combination really takes place between the carbon and oxygen? If it do, in what proportion do they combine? How does it appear that the azote, which forms four-fifths of the air which passes through the furnace issues unaltered?

8. To supply satisfactory answers to these questions, it is only necessary to bring the two constituents of common air separately into the presence of carbon under the conditions necessary to favour combination, and to ascertain their weights before and after the development of the phenomena.

Fig. 1.

Let a glass flask containing sixteen grains of oxygen gas be inverted over mercury, as represented in fig. 1, and let a piece of carbon weighing more than six grains, supported in a platinum spoon, be introduced into it by means of a piece of bent platinum wire; let the sun's rays, concentrated by means of a burning-glass, be then directed upon the carbon through the glass flask. The carbon will be ignited by the solar heat, and will burn in the oxygen with great splendour.

* See Tract on Air.

When the combustion has ceased and the gas contained in the flask has cooled, it will be found that the mercury in the neck of the flask will stand at exactly the same elevation as it did before the combustion. The gas contained in the flask has therefore the same volume as before, nevertheless it is easy to show that it is by no means the same gas.

In the first place, if it be weighed, it will be found to weigh 22 instead of 16 grains; and if the unburned residue of the carbon be weighed, its weight will be found to be 6 grains less than it was before the experiment. The inference is, that 6 grains of the carbon have combined with the 16 grains of the oxygen previously contained in the flask, but that in thus combining, the carbon has not made any change in the volume of the gas.

If the gas contained in the flask be examined by the usual tests, it will immediately appear that it is no longer oxygen. No combustible will burn in it, and it will not support life by respiration. In fine, it will be found to be identical with the noxious gas called choke-damp, and to possess all the chemical characters of the gas called CARBONIC ACID.

If the same flask, similarly filled with nitrogen gas or azote,* be submitted to a like experiment, the result will not be the same. The solar rays concentrated on the charcoal will still render it red hot, but it will not burn nor undergo any other change. On removing the focus of solar rays from it, it will become gradually cool, and when removed from the flask will have the same weight as when introduced into it. The azote which fills the flask will also be found to be unaltered.

It follows, therefore, that the FIRE produced when carbon burns in common air is nothing more than the heat and light developed in the formation of carbonic acid, by the combination of the carbon with the oxygen of the surrounding air, and that these substances combine in the proportion of 6 parts by weight of carbon to 16 of oxygen.†

9. It has been already shown‡ that hydrogen combines with oxygen in the proportion of 1 part by weight of the former to 8 of the latter to form water, and that if the combination be formed in a pure or nearly pure atmosphere of the gases it is instantaneous and accompanied by an explosion. If, however, the combination take place, as it may, in common air, the phenomena will be very different.

If pure hydrogen, compressed in a bladder or other reservoir, be allowed to issue from a small aperture, a light applied to it

* See Tract on Air.

† More precisely 6·04 or 6·12 of carbon to 16 of oxygen.

‡ See Tract on Water.

will cause it to be inflamed. It burns tranquilly without explosion, producing a pale yellowish flame and very feeble light, but intense heat. This is the effect attending the gradual and continual combination of the hydrogen, as it escapes from the aperture, with the oxygen of the surrounding air. It may be asked why the hydrogen issuing from the aperture does not combine with the oxygen of the air without the application of a flame to it? And also, why being once inflamed by the application of such a body, its continued application becomes unnecessary?

These questions are easily resolved. The hydrogen gas has an affinity or attraction for oxygen, which is not strong enough to cause their combination at common temperatures, but when the temperature of the hydrogen is greatly elevated, its attraction for the oxygen becomes so exalted, that it enters into instant and spontaneous combination with it. Now by applying the flame of a lamp or candle, or any other burning body, to the jet of hydrogen, its temperature becomes so greatly raised, and its attraction for oxygen consequently so exalted, that it enters directly into combination with the oxygen of the air which is in immediate contact with it at the moment.

10. But it is also asked, How the continuance of the combination and the consequent maintenance of the flame takes place—the candle or lamp which produced its commencement being withdrawn? This is explained by the great quantity of heat produced by the combination of the hydrogen with the oxygen. The commencement of the combination being produced by the candle or lamp, the hydrogen and oxygen themselves in the act of combining develop an intense heat, and the succeeding portion of hydrogen gas being in contact with them becomes heated and combines like the former with a fresh portion of oxygen. In the same manner, the heat developed by these being shared by the succeeding portion of gas, a further combination and development of heat takes place, and so on. Thus the combustion being once commenced, the heat necessary for its maintenance and continuance is developed in the process itself, which accordingly goes on without the necessity of being again kindled by the application of any flame.

The continuance of the combustion of carbon, whether in pure oxygen gas or in common air, is explained in the same manner.

11. The combustion of carbon differs from that of hydrogen in this, that the former takes place without the production of *flame*. The charcoal being heated to redness, and still in the solid form, enters directly into combination with the oxygen of the surrounding air, and the carbonic acid which is formed being a gas which is not

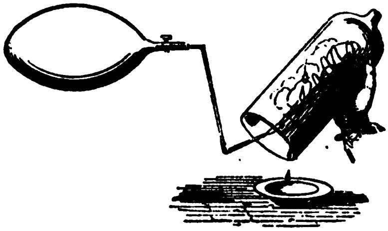
luminous nor visible, the carbon disappears. But in the case of hydrogen, the heat produced by the combustion is so intense as to render the gas itself luminous, just as intense heat will render a mass of iron red hot or white hot. When gas becomes thus luminous it is called *flame.*

12. Flame, therefore, must be understood to be nothing more than matter in the aëriform, gaseous, or vaporous state, rendered so intensely hot as to be incandescent, and to emit light, just as would a bar of iron taken from a furnace.

13. It is easy to show that, comformably with what has been already demonstrated in our Tract on Water, the product of the combustion of hydrogen is the vapour of water, which by exposure to cold can be reduced to the liquid state.

If a glass jar be held over a jet of inflamed hydrogen, as represented in fig. 2, the aqueous vapour formed by the combination of the hydrogen with the oxygen of the surrounding air, will be condensed upon the inside of the jar, and will appear first as a cloudy dew upon it, and, as the process is continued, it will increase in quantity, and, trickling down the side of the jar, may be received in drops by a dish placed beneath it.

Fig. 2.



14. As we have stated above, the principal constituents of every species of combustible, whether used for heating or lighting, are carbon and hydrogen, and the products of their combustion are therefore carbonic acid and water, the latter being evolved in the form of vapour.

15. It happens, however, rarely that the hydrogen is evolved in the pure state. It is more generally combined with a certain dose of carbon, forming a compound gas called CARBURETTED HYDROGEN. This gas burns with a much whiter and more luminous flame than that of pure hydrogen, and it is therefore much better fitted for the purpose of illumination.

16. That the flame owes its whiteness and illuminating power to the carbon with which the gas is charged, is proved by the fact,

that the more carbon the gas is charged with the whiter and brighter is the flame.

17. There are two sorts of carburetted hydrogen, one of which contains twice as much carbon as the other: the one called light carburetted or proto-carburetted hydrogen, and the other heavy carburetted or bi-carburetted hydrogen, or olefiant gas.

18. In light carburetted hydrogen 6 parts, or more exactly 6·12 parts by weight of carbon are combined with 2 of hydrogen, and heavy carburetted hydrogen contains twice that proportion of carbon.

Light carburetted hydrogen is a little more than half the weight of its own bulk of common air. When pure it has no odour; and it burns with a yellowish flame much more luminous than that of pure hydrogen. Like pure hydrogen it forms a highly explosive mixture when combined in a certain proportion with common air, or, more properly, with the oxygen of common air, since the azote has no influence on the phenomenon.

19. It is this gas which, under the name of FIRE-DAMP, produces occasionally such disastrous explosions in coal mines. Being contained in large quantities in the fissures and interstices of the seams of coal, it issues from them in the workings of the mines, and being one half lighter than common air, it first collects at the top of the working. After a certain time, by a common property of all gases, it mixes with the air, and attains occasionally that proportion which renders it explosive. If a light be brought into it in this state an explosion takes place, producing those destructive consequences to the operatives who happen at the moment to be present, with the details of which the public has been so often rendered familiar.

20. This gas is also that which over marshy ground and stagnant pools produces the appearance called WILL O' THE WISP, JACK O' LANTHORN, or ignis fatuus. The gas is produced by the decomposition of vegetable and animal matter, and rising from the ground or from the water is spontaneously ignited.

Fig. 3.

21. It is easy to verify this by actually collecting the gas from any stagnant pool. For this purpose, take a common funnel used for decanting liquors, and a bottle or beer glass; immerse the latter in the water, and, when it is filled, invert it under the water and raise it above the surface, keeping the mouth under the water. Then bring the inverted funnel under its mouth, the neck entering the bottle or glass; agitate the funnel, and the gas

will rise from the water in bubbles and will collect in the upper part of the bottle or glass.

The manner of performing this experiment is shown in fig. 3.

When the gas is thus collected its inflammable nature may be ascertained by applying a light to it as it issues from the bottle.

22. Heavy carburetted hydrogen burns with a much whiter and more luminous flame. Its weight is very nearly equal to that of common air, and, therefore, nearly double that of the light carburetted hydrogen; hence it has acquired the epithet "heavy."

The products of the combustion of both sorts of carburetted hydrogen are carbonic acid and water, the former proceeding from the combination of the carbon, and the latter from that of the hydrogen with the oxygen of the air.

These points being understood it will be easy to render intelligble the effects which are developed in all ordinary cases in which FIRE or COMBUSTION takes place.

23. The species of combustible used as fuel with which we are most familiar in this country is PIT COAL.

This mineral, exclusive of some extraneous and incombustible ingredients which it contains in very small proportions, consists of carbon and carburetted hydrogen of both kinds.

The proportion of carbon varies in different sorts of coal from 80 to 90 per cent., the hydrogen varying from 3 to 6 per cent., and the remainder consisting of oxygen and azote.

In the heavy coal of Wales, called anthracite, the proportion of carbon is above 90 per cent., while that of the hydrogenous gases is only 3 or 4 per cent. In the bituminous coal of Northumberland the proportion of carbon is about 87 per cent., and that of hydrogen from 5 to 6 per cent.

24. When a fire composed of such fuel is properly kindled and supplied with a draught of air necessary to sustain the combustion, the carbon will continue to combine with its proper proportion of oxygen, producing the corresponding quantity of heated carbonic acid, and rendering the solid part of the fuel red and luminous; and the hydrogenous gases will at the same time combine with their respective proportions of oxygen, producing carbonic acid and watery vapour, and rendering the gases as they issue from the fuel luminous, or, what is the same, converting them into flame.

The flame will be faintly luminous and bluish if any part of the gases be pure hydrogen, it will be yellowish and a little more luminous if they be light carburetted hydrogen, and it will be very white and very luminous if they be heavy carburetted hydrogen.

Thus all the phenomena exhibited by a common coal-fire,—*the red* unflaming fuel—the faint blue flames occasionally seen,

—and, in fine, the white brilliant flame which most commonly issues from the fissures of the coal, are severally explained and accounted for.

25. It has been shown that in combustion 6 parts, by weight, of carbon combine with 16 of oxygen, or, what is the same, 1 part with $2\frac{2}{3}$. It has also been demonstrated, that in the combustion of hydrogen, 1 part by weight of that gas combines with 8 of oxygen. Now by these simple numerical data may be easily explained the effects of a common coal-fire upon the air which feeds and sustains it.

26. It is thus found, that in burning 10 lb. of coal the oxygen contained in 1551 cubic feet of air is altogether absorbed.

To keep the atmosphere of a room in which a fire of such coal is burned fresh and pure, it would be, therefore, necessary to supply fresh air at the rate of 155 cubic feet for every pound of coal which is burned.*

27. Wood is a combustible generally used for the production of artificial heat in countries where coal is not so cheap and abundant as in England. This fuel, like coal, consists principally of carbon and hydrogen in various proportions, according to the sort of wood. All kinds of wood contain also a proportion of oxygen, as a constituent, much greater than is found in coal.

Wood, when green, contains a considerable proportion of water. In the combustion of such wood, a large proportion of the heat developed is absorbed in the evaporation of this water, and is, therefore, lost for heating purposes. Wood used as fuel should, therefore, be kept until this water, or the chief part of it, has been evaporated. For the same reason wood kept for fuel should be as little exposed to moisture or damp as possible.

28. All fatty, oily, and waxy substances are combustible, whether in the liquid or solid state. They consist of the same constituents as coal and wood, but combined somewhat differently, and in different proportions. Most of this class, burning with flame of more or less brilliancy, are used for the purposes of artificial illumination.

Whale, sperm, olive, and cocoa-nut oils, wax, spermaceti, and tallow are examples of this class of combustibles.

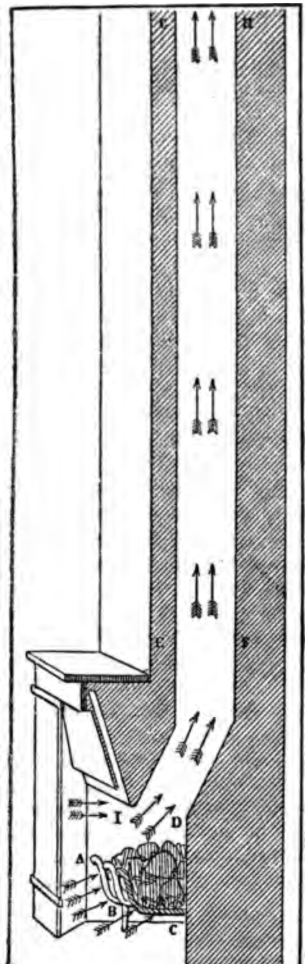
29. Whatever be the sort of combustible, or whatever be the purpose to which it is applied, whether for heating or lighting, it will be evident from the explanations which have been here given, that the combustion cannot be maintained with the necessary

* In the preceding explanation we have omitted to take into account the effect of a small proportion of oxygen which enters into the composition of coal. This, however, is so insignificant, that it would be needless to complicate the calculation by introducing it.

activity unless expedients be provided for the supply of the quantity of oxygen which must enter into combination with it.

30. The construction of grates, stoves, and chimneys is therefore designed to attain this end by causing such a volume of common air to pass through the fuel as is necessary and sufficient to combine with it. The more air which thus passes through the fuel, the more rapid and abundant will be the combination, and the more active and vivid the combustion.

Fig. 4.



31. The current of air which passes through a common grate is produced by the draught of the chimney. The column of air included in the chimney, being raised to a higher temperature than that of the external air, is rarefied and lighter, bulk for bulk, than the external air, and is proportionately more buoyant. It has therefore a tendency to ascend like that which oil would have in water. As it ascends the air from the room must rush in to fill its place. A part of this air will pass through the bottom and front of the grate, and a part will enter at the opening of the fire-place over the grate. This will be more easily understood by fig. 4. The front of the grate is A B, and the bottom B C, having the ash-pit below it. The opening over the grate is A I, and E F G H is the flue of the chimney. The ascensional force of the column of air in the flue is measured by the difference between its weight and that of an equal volume of the external air. The air which replaces that which ascends in the flue enters the bottom B C, the front B A of the grate and the

opening A I above it, as indicated by the arrows. The former portions, passing through the burning fuel, supply to it the oxygen gas necessary to combine with it, and thus maintain the combustion. These portions after passing through the interstices of the fuel, and after the oxygen or a part of it, has combined with the fuel, issue from the top of the fuel, being then a mixture of azote, such portion of oxygen as may not have combined with the fuel, carbonic acid and aqueous vapour, the latter being the products of the combination of the oxygen with the carbon and the hydrogen of the fuel.

All these gases issuing from the burning fuel at a high temperature, and mixing with the cold air which enters the chimney through the opening A I, render the column of air in the flue so warm as to give it the buoyancy necessary to sustain the draught.

When the fire is first kindled in the grate, if the air in the chimney have the same temperature as the external air, it will have no buoyancy, and there will be no draught. In this case the chimney will generally be found to smoke. This inconvenience may be sometimes removed by opening the windows, so as to fill the room with air as cold as the external air, and therefore colder than the air in the chimney. If, however, this be found insufficient, the air in the flue may be warmed and the necessary draught produced by holding under the chimney any blazing combustible.

The draught through the grate may be greatly increased in intensity by stopping up, either partially or completely, the opening A I. By this expedient, all the air necessary to replace that which ascends in the chimney must pass through the fuel in the grate. If the magnitude of the opening be for example three times the magnitude of the front and bottom of the grate, four times as much air will thus pass through the fuel as would pass through it when the opening AF is not closed, supposing the draught in the chimney to be the same in both cases.

But, in fact, the draught in the chimney will be greatly augmented by this process: for, so long as the opening A I is not closed, the air which fills the chimney will consist of a mixture of that which passes through the burning fuel, which is raised to a high temperature, and the much larger portion which passes into the chimney through the opening A I, and which, being cold, lowers the temperature, and therefore diminishes the buoyancy of the air in the chimney. But when all the air which passes through A I, by closing that opening, is made to pass through the burning fuel, it is raised to a high temperature, which not being lowered by admixture with any air not passing through the fuel, fills the chimney with air raised to a very elevated temperature,

and which therefore produces in the chimney a much stronger upward current.

Thus the effect of closing the opening A I is to stimulate the fire not only by causing to pass through it all the air which previously entered the opening A I, but also by augmenting the draught in the chimney.

32. From what has been explained above, it will be perceived that an open fireplace such as is represented in fig. 4 serves the double purpose of warming and ventilating.

All the air which enters the chimney, whether it passes through the grate or through the opening above the grate, must be replaced by an equal volume of fresh air from without, which must find its way through the interstices of doors and windows, or through other openings provided expressly for its admission. That part of the air which passes through the grate subserves the double purpose of warming and ventilation. It warms by stimulating and maintaining the combustion of the fuel, and it ventilates by leaving in the room a void into which an equal volume of fresh air must enter. That portion of air which enters the chimney through the opening above the grate has no effect direct or indirect in warming, but its effect in ventilating is just so much greater than that of the air which passes through the grate, as the magnitude of the opening above the grate is greater than the magnitude of the spaces between the bars in the front and bottom of the grate.

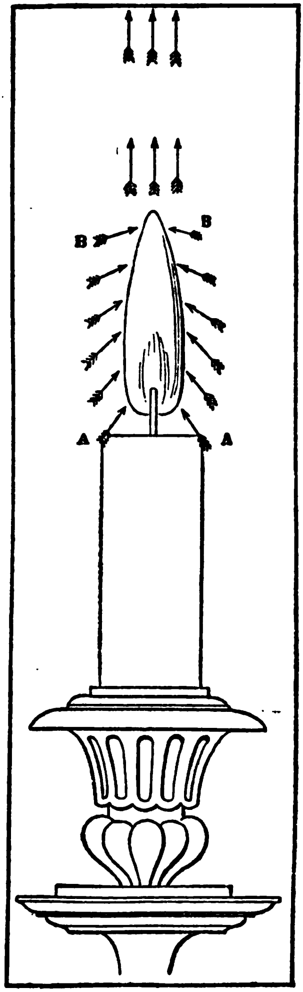
33. The necessity for ventilation is so much the greater as the room is smaller and lower, and as the causes of the pollution of its air are more numerous and active. The air of a room is deprived of its oxygen and rendered unfit for respiration by several causes. Each person who is present in the room absorbs oxygen by respiration. It is calculated that an adult of average size absorbs about a cubic foot of oxygen per hour by respiration, and consequently renders five cubic feet of air unfit for breathing. It is also computed that two wax or sperm candles absorb as much oxygen as an adult. It follows, therefore, that to keep the air of a room pure, five cubic feet for every person, and two and a half cubic feet for every candle in the room should pass per hour into the chimney, or through some other opening, and an equal volume of fresh air should be admitted.

34. Plants give out oxygen by day, but absorb it by night. Their presence in a room by day is therefore innocuous, but at night they have the effect of polluting the air, and should never be admitted except where there are ample means of ventilation.

35. A crowded room, illuminated with many candles and lamps, as generally happens, without a fire, soon becomes filled with in which there is a deficient proportion of oxygen and a

corresponding volume of carbonic acid, unless means be provided, which is rarely the case, for other ventilation besides that of the chimney. Hence it arises that persons of delicate habits, especially those whose lungs are defective, in such a room, soon become sensible of general uneasiness, and are often affected with headache.

Fig. 5.



36. The manner in which the flame of lamps and candles is produced and maintained will require some explanation.

When a candle is lighted, the heat developed at the extremity of the wick melts the wax or tallow immediately below it, and thus liquefied, it is drawn up through the insterstices of the wick by the force called capillary attraction. When it comes in contact with the flame, it boils, and is converted into vapour, which rises over the wick. This vapour having a very high temperature, and exercising a strong attraction for the oxygen of the surrounding air, enters into combination with it, and becoming luminous, forms the flame around and above the wick. Within the flame arises a constant current of the vapour of the combustible, and outside it currents of air carry to the surface of the flame the oxygen which produces the combustion and the light. The combustible vapour and the oxygen meeting at the surface of the flame, there enter into combination, and the vapour burns. Within the flame no combustion takes place, and no light is produced.

In fig. 5 the wick and flame are represented. Within the flame currents of combustible vapour proceed from the wick to all parts

of the surface of the flame. The arrows at the sides of the flame outside its surface represent the currents of the surrounding air produced by the heat of the flame; the oxygen, being attracted by the intensely heated combustible vapour, approaches it, and, by combining with it, sustains the combustion and produces the light. The arrows above the flame indicate the current of heated air, carbonic acid and aqueous vapour, the products of the combustion which form an ascending column above the flame.

It will be apparent from what has been here stated, that the luminous part of the flame is merely superficial. The vapour within the surface of the flame not having yet come into contact with the oxygen, and therefore not having entered into combustion, cannot be luminous. The flame, therefore, so far as relates to light, is hollow, or rather it is a column of combustible vapour, the surface being the only part which burns, and therefore the only part which is luminous. As this vapour ascends from the interior of the flame, it comes successively into contact with the oxygen of the air, is burnt, and becomes luminous, the column of light gradually contracting in diameter until it is reduced to a point. The flame thus tapers to a point until all the vapour produced by the boiling matter on the wick receives its due complement of oxygen, and passes off. It speedily loses that high temperature which renders it luminous, and the flame terminates.

37. In lamps of various construction, expedients are adopted to increase the magnitude of the luminous surface of the flame, and the intensity of the combustion. This is effected by modifying the form and magnitude of the wick, by feeding it with an abundant supply of oil, and by maintaining strong currents of air at all parts of its surface to sustain the combustion.

The most common form of wick used for lamps of strong illuminating power, is that of a hollow cylinder, varying from an inch to three inches in circumference. This wick being attached at its base to a small thin ring of metal is let down into the reservoir of oil, through a space included between two concentric tubes, one of which has a less diameter than the other, the space between them being a little wider than the thickness of the wick. The wick is from two and a half to three inches long, and descends through this space between the tubes to a certain depth. This space communicates with the reservoir of oil from which the oil is
up either by the action of a pump worked by a main spring,
h the intervention of wheelwork, as in the Carcel lamp, or
more direct action of a strong spiral spring as in the
mp, or by the pressure of oil contained in a reservoir

above the level of the wick, as in the old English ring-lamp called the Sinumbral lamp, and a variety of other forms constructed on the like principle.

The flame issuing from such a wick is obviously a hollow cylinder, and requires to be fed with air, both at its exterior and interior surfaces. A current of air in contact with the interior surface of the flame is maintained by carrying the lesser of the two tubes between which the wick is included, down through the burner, and leaving it in communication with the external air. The exterior of the flame is exposed to the air and produces currents by its own heat, in the same manner as the currents already described, surrounding the flame of a candle.

But in the case of lamps with cylindrical burners these currents, both exterior and interior, are greatly augmented in intensity by the addition of a cylindrical glass-chimney of considerable height, the inner diameter of which a little exceeds the exterior diameter of the wick. This chimney being open at its base, and confining a column of air of its own height, acts upon the combustion of the lamp exactly as a common chimney acts on the combustion of fuel in a grate. The air which enters at the bottom, between this chimney and the burner, rises in a cylindrical current around the exterior of the wick, and passing in contact with the exterior surface of the combustible vapour proceeding from the oil, ignites it at that surface. The column of air which ascends at the same time through the inner tube passing in contact with the inner surface of the vapour ignites it in like manner. In this manner, a thin cylinder of oily vapour rising from the wick is kept in a state of vivid and constant combustion, both on its interior and exterior surfaces.

The force of these currents, exterior and interior, depends on the buoyancy of the column of air included in the chimney, and which also extends to a considerable height above it. The air after passing the flame of the lamp, being at a very high temperature, the glass-chimney itself becomes intensely hot. The column of air within the chimney being thus heated, it ascends to a considerable height above the chimney before it is cooled down to the temperature of the surrounding air. The force of the draught which maintains the currents around the flame is then determined by the difference between the weight of the column of air, extending from the base of the chimney to that height above it, at which the temperature of the ascending column becomes equal to that of the external air, and the weight of an equal volume of the external air.

This explanation of the combustion of the oil in a cylindrical

burner will be more clearly comprehended by reference to fig. 6, where C C represents the interior, and A A the exterior tube, between which the wick is included. The oil is forced up to the wick in the space between these tubes; G H G H is the chimney, open at the base B B. The air ascends as indicated by the arrows between G H and D A, and passes in contact with the external surface of the flame, and it rises through the internal tube C C, passing in contact with the internal surface of the flame, as indicated by the arrows. The cylindrical flame, ascending from the wick, is represented at A M C N, and the course of the ascending column in the chimney is represented by arrows.

Fig. 6.